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Impacts of the 1993 Flood on the Mississippi and Illinois Rivers

Principal Investigator
David TaWei Soong

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Illinois State Water Survey
Hydrology Division
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Prepared by the:
Hydrology Division
Illinois State Water Survey
2204 Griffith Drive, Champaign, IL 61820

Principal Investigator:
David TaWei Soong, P.E., Ph.D.
Professional Scientist and Director
Office of Hydraulics & River Mechanics

Project Personnel:
Maitreyee Bera, Assistant Supportive Scientist
Nancy Johnson, Assistant Supportive Scientist
Ganapathi Ramamurthy, Professional Scientist
James Slowikowski, Associate Supportive Scientist
Office of Hydraulics & River Mechanics

Report Prepared for the:
Illinois Environmental Protection Agency
William H. Ettinger, Project Manager,
in partial fulfillment of project requirements

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ABSTRACT

Hydrology, climate, geology, land uses, and land covers are major factors contributing to the quality and quantity of water in a river basin. The 1993 flood was an unusual hydrometeorologic event that had significant effects on these factors. In order to determine the flood's impact on the Illinois and Mississippi Rivers, the Illinois State Water Survey and the Illinois Environmental Protection Agency (IEPA) conducted a joint investigation of selected water and sediment parameters in these two rivers, including inorganics and organics in water (CORE1 and PEST1 groups in IEPA's ambient water quality program), organics in sediment (CORE3), and nutrients and metals in sediment (CORE4.) Data were collected from four stations on the Mississippi River bordering Illinois and two stations on the lower Illinois River from December 1993 to June 1994.

The collection, preservation, and transportation of the water and sediment samples followed the procedures given in the IEPA *Quality Assurance and Field Methods Manual.* Lab analyses of most CORE 1, PEST 1, and CORE4 parameters were completed by the time this report was prepared. The results showed that concentrations of many water quality parameters were below detection limits during the study period. For those parameters that showed detectable values, concentrations were below established standards. These parameters were chloride, sulfate, alkalinity, and totak kjeldahl nitrogen (TKN) in CORE1; and alachlor, atrazine, cyanazine, and metolachlor in PEST1. At the same time, it was noted that certain parameters that did not show detectable values during the study period had been present before the flood. In the limited CORE3 samples, traces of PCBs were found in sediment at Valley City on the Illinois River but none were found at other stations. Overall, sediment samples contained high concentrations of TKN, total phosphorous, and heavy metals.

Comparisons to historical data were made when available. Historical data were defined from the first recorded value through March 31, 1993. Using these data, it was possible to determine whether the values of parameters after the flood were elevated or reduced. In some cases, new maximum and minimum values for those parameters were identified.

INTRODUCTION

Illinois has abundant water resources in its lakes, streams, and rivers. Three large rivers within or bordering the state supply water for domestic, industrial, livestock, and agricultural uses as well as for cooling processes in thermoelectric power generation. They also generate commercial and recreational opportunities for the citizens of the state, and provide habitats to thousands of species of plants and wildlife. The quality of these rivers plays a fundamental role in the overall health of the environment and has a direct effect on the economic development of the state not to mention the many communities along their courses.

It is now known that the quality of natural river water will degrade to such a degree that the water cannot be used, contrary to the conventional concept of water as an unlimited, undegradable resource. Therefore it is important to know the water quality status of these large rivers and to be aware of the effects of natural and human factors, including changes in land covers and land uses, hydrologic modifications, urban development, climate changes, and floods or droughts.

The flood of 1993 was an unusual and significant hydrometeorologic event. It is distinct from all other record floods in terms of its magnitude, severity, damage, and the season in which it occurred. Precipitation during April through July 1993 produced several floods of record in many areas of the Upper Mississippi River (UMR) basin. Concentrated and intense precipitation fell on vast farmlands in the basin, especially between mid-June and early August. Flows inundated many areas that had not been affected by previous floods. The flooding not only caused tremendous runoff of agricultural chemicals and pollutants from recently planted land and urban areas, but also eroded top soils. These pollutants were transported to the rivers and infiltrated ground-water reservoirs.

The vast inundation of point and nonpoint pollutant sources may make the 1993 flood one of the worst scenarios in terms of the rivers' water quality. Rajagobal (1993) estimated that during the flood 175 metric tons of atrazine was transported through Baton Rouge, LA, on the Mississippi River between July 7 and August 12, while the average annual load is 160 metric tons.

Many pollutants, such as nutrients, pesticides, metals, and bacteria, were brought to the rivers' main stems through different paths. Many of these pollutants were dissolved in the water and transported through overland flows to tributaries and then to the main stems, while others, such as phosphorus, pesticides, and heavy metals, were attached to sediment, especially fine sediment, which served as the transport medium. Nutrients, such as nitrate, also entered groundwater through infiltration from uplands or river valleys and were later released to streams during low flows. In the transport process, heavier suspended particles settled whenever the floodwater slowed down. The UMR has many sediment "sink" areas in main channels upstream of locks and dams or in channel borders, sloughs, backwater lakes, and side channels. Pollutants were then gradually released from the sediment to water by natural chemical, biological, or physical processes, such as currents and waves generated by winds, boats, or barges, which caused sediment resuspension and redistribution. The effects of flooding on water quality hence could be felt over a long period of time.

The areas most affected during the 1993 flood were along the Illinois border. By the end of August, record flooding was reported for the stretch of the Mississippi River from Savanna, IL (river mile, RM, 538), down to Cairo, IL (RM 00); for the lower Illinois River, including Valley City and Hardin; and for the lower reaches of the Iowa, Des Moines, and Missouri Rivers.

Study Purpose

In order to determine the changes in water quality as a result of the 1993 flood, the Illinois State Water Survey (ISWS) and the Illinois Environmental Protection Agency (IEPA) have conducted a joint project to investigate the flood's impacts on water quality on the Mississippi and Illinois Rivers. By selecting those parameters that IEPA measures routinely, comparisons could be made with the established baseline information. This work was done in support of the Ambient Water Quality Monitoring Network (AWQMN) of the IEPA, which assesses the water quality of the state's surface water resources.

Study Scope

Study Sites

Table 1 lists the six IEPA AWQMN stations selected for monitoring.

Table 1. Study Sites

Station code	*River*	*Location*	*River mile**
D 32	Illinois	Valley City	61.4
D 01	Illinois	Hardin	21.5
M 04	Mississippi	Fulton	511.8
K 04	Mississippi	Keokuk	364.2
J 05	Mississippi	Upstream of L&D 26 (Piasa Creek boat launch ramp)	214.4
I 84	Mississippi	Thebes	43.7

*Note: River miles (RMs) are given for each river. The RM at Grafton is used to represent J 05.

The Fulton (M 04) and Thebes (I 84) stations on the Mississippi River provide information on the extreme northern and southern ends of the state. The remaining four stations (K 04, J 05, D 01, and D 32) provide data on the most severely flooded areas of the Mississippi and Illinois Rivers in west-central Illinois. The locations of these six stations and the transect where data were collected are presented in figure 1.

Sample Constituents

Four groups of water and sediment samples were collected: CORE1 and PEST1, which contain the inorganic and organic water quality parameters, and CORE3 and CORE4, which contain organics and nutrients and metals in sediment. The constituents of each group are listed in table 2. Note that PEST1 includes PEST1 and CORE2 constituents.

Table 2. Sample Constituents

CORE1 - Inorganics in Water

Cyanide	Arsenic	Phenol	Fluoride	Mercury
Chloride	Sulfate	Total Acidity	Alkalinity	Total Kjeldahl Nitrogen

PEST1-Pesticidesin Water

Alachlor	Atrazine	Butylate	Captan	Chloropyrifos
Cyanazine	Diazinon	Fonofos	Malathion	Methyl Parathion
Metolachlor	Metribuzin	Phorate	Terbufos	Trifluralin

CORE2 - Organics in Water

PCBs	Aldrin	Dieldrin	Total DDT	O, pDDE
p.p'DDE	o, pDDE	o, p' DDD	o, p DDT	p, p DDT
Total Chlordane	Chlordane trans isomer	Nonachlor cis isomer	Nonachlor trans isomer	Endrin
Methoxychlor	Hexachlorocyclohexane	gamma BHC Lindane	Pentachlorophenol	Chlordane cis isomer

CORE3 - Organics in Sediment

PCBs	Aldrin	Dieldrin	Total DDT
o, p DDE	p, p DDE	O, p DDD	O, p DDT
p, p' DDT	Total Chlordane	Chlordane cis isomer	Chlordane trans isomer
Nonachlor cis isomer	Nonachlor trans isomer	Endrin	Methoxychlor
Hexachlorocyclohexane-alpha BHC	Gamma BHC Lindane	hexachlorobenzene	Pentachlorophenol
Heptachlor	Heptachlor epoxide	Lindane	

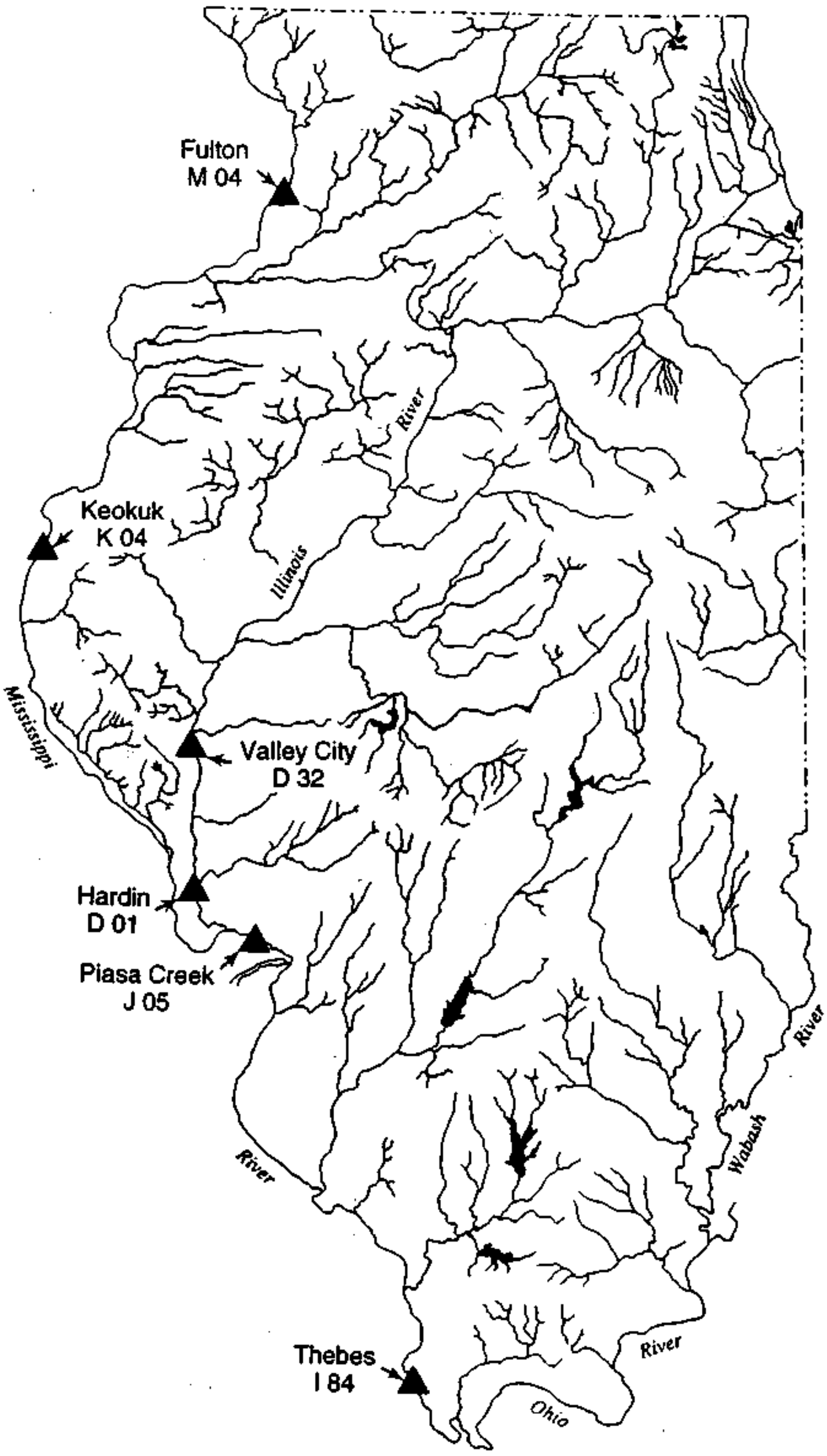

Figure 1. Locations of Sampling Stations on the Illinois and Mississippi Rivers

Table 2. (Continued)

COM4 - Sediment Metals

% Volatile Solids	Total Kjeldahl N	Total Phosphorus	COD	Iron
Arsenic	Cadmium	Chromium	Copper	Lead
Manganese	Mercury	Zinc		

In addition to the constituents listed in table 2, common water quality indicators such as pH, dissolved oxygen (DO), conductivity, and water temperature were also measured on each trip.

Study Period

Water and sediment samples were collected over a seven-month period from December 1993 through June 1994. The inorganic water parameters (CORE1) are routinely collected at all of the selected AWQMN stations, but the parameters for organic water and inorganic and organic sediment were additional. Also, surficial sediment samples were collected on the first and last trips of the study. The IEPA normally samples the four west-central stations at six-week intervals. For this post-flood monitoring project, however, the sampling frequency at these stations was doubled to every three weeks. The remaining two stations (Fulton and Thebes) were sampled three times during the project (approximately every 15 weeks). The IEPA currently samples the Fulton (M 04) station on a quarterly schedule, so these additional samples approximately doubled the normal sampling frequency. The Missouri office of the U.S. Geological Survey (USGS) currently samples the Thebes (I 84) station every other month, so three additional samples at this station increased the normal sampling frequency by one-third. The dates of field data collection are shown in table 3.

Table 3. Schedule of Data Sampling

Sampling stations	*Weeks of sampling*
Mississippi River	
Hardin, Valley City, Lock & Dam 26, Keokuk	December 13, 1993; January 3, 1994; January 24, 1994; February 14, 1994; March 7, 1994; March 28, 1994; April 18, 1994; May 9, 1994; May 30, 1994; June 20, 1994
Illinois River	
Fultin, Thebes	December 13, 1993; March 28, 1994; June 20, 1994

Protocol for Data Collection

The collection, preservation, and transportation of water and sediment samples followed the procedures given in the IEPA *Quality Assurance and Field Methods Manual* (IEPA, 1991). Depth-integrated water samples were collected at four equal width increments using an epoxy-coated weighted bottle sampler. Samples for organics analysis were placed into a 1-gallon amber glass bottle while samples for other parameters were composited in a churn splitter and then subsampled. Dissolved metal and nutrient samples were filtered through a .45-micrometer (urn), 147-millimeter (mm) cellulose acetate filter. Hydrolab data (pH, DO, conductivity, and temperature) and total organic carbon (TOC) samples were collected at mid-channel. Sediment samples were collected using an epoxy-coated petite ponar dredge and were homogenized in a stainless steel pan prior to being placed in bottles. Both water and sediment samples were transported in insulated coolers for delivery to the appropriate laboratories.

Lab Analysis and Retrieval of Results

The IEPA labs in Champaign and Springfield performed all sample analyses. CORE1, CORE3, and CORE4 samples were delivered to the IEPA lab in Champaign. PEST1 samples were delivered to the IEPA lab in Springfield. Laboratory results were entered in a STORET database maintained by IEPA. They can be retrieved from STORET once they have been entered.

Total Samples Collected

The ISWS completed ten sample collections at designated intervals between December 1993 and June 1994. The total number of samples collected is summarized in table 4.

Table 4. Total Samples Collected

Site	*CORE1*	*PEST1*	*CORE3*	*CORE4*
ValleyCity	10	10	3	3
Hardin	10	10	3	3
Fulton	3	3	3	3
Keokuk	10	10	3	3
L&D 26	10	10	3	3
Thebes	3	3	3	3

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The main draft of the report was typed by Lacie L. JefFers. Technical editing was done by Sarah Hibbeler, and final graphics were prepared by Linda Hascall.

BACKGROUND

Background information pertaining to the natural setting and human activities in the watersheds of the sampling stations is given here to illustrate the factors that may affect the water quality parameters in the study. Climate, hydrologic events, and human-induced changes can instigate processes, such as flooding, infiltration, and sediment entrenchment and deposition, which act upon natural factors and affect water quality. The 1993 flood caused several of these physical processes to occur with unprecedented magnitude. A brief summary of the climatologic and hydrologic conditions during the 1993 flood and the study period is also given in this section.

Description of Watersheds

Upper Mississippi River (UMR) Stations

As the UMR flows from the northern to the southern extremes of Illinois, its hydrologic character varies greatly. Above the northern border of the state, the river's drainage area is mostly limited to portions of Minnesota and Wisconsin, and its average flow is approximately 46,000 cubic feet per second (cfs) or 1,300 cubic meters per second (cms). In addition to the Missouri River, major tributaries to the UMR along the reach bordering Illinois include the Illinois River with a drainage area of 28,900 square miles (sq mi), the Des Moines River (14,500 sq mi), the Iowa River (12,600 sq mi), and the Rock River (10,600 sq mi). Major tributaries to the Mississippi River upstream of Illinois (as defined by the station at Dubuque, IA) are the Minnesota River, with a drainage area of 17,000 sq mi, the Wisconsin River (11,000 sq mi), and the Chippewa River (9,400 sq mi). The Missouri River, which enters the UMR upstream of St. Louis with a drainage area of 529,350 sq mi, is the second largest river in the conterminous United States after the entire Mississippi River. In order to maintain a 9-foot navigation channel, 26 locks and dams were built. The basin's surficial geology comprises primarily glacial deposits that have a relatively high infiltration and storage capacity.

Fulton. Fulton is located downstream of Lock & Dam (L&D) 13 at RM 512. Across the river at Clinton, IA, is a USGS gaging station. The present morphology of the river above Fulton is "island braided" with divided flow around numerous islands and bars. Numerous side channels and nonchannel areas characterize this reach. These are high areas of biological productivity. Thirteen locks and dams on the main stem as well as numerous wing dams, closing dams, and annual dredging activities serve to maintain the commercial navigation system. The Maquoketa River is the only tributary between the Dubuque and Fulton stations.

Keokuk. The reach between Fulton and Keokuk is a transitional one between the upper and lower pooled river reaches. Topography changes from high bluffs near Cassville to a more rolling landscape near Keokuk. Forested areas become less prominent in the lower parts of this reach. There is a high relative distribution of woody vegetation in the floodplain except in the Quad Cities area on Pool 15. Nonchannel waters and side channels become less extensive and are replaced by main channel borders as the dominant water type at the lower end of this reach. Use of the river for commercial navigation increases in a downstream direction, with double the tonnage in Pool 19 than in Pool 2. This reach is characterized by a series of nine pools maintained by the operation of locks and dams, wing dams, closing dams, and dredging. More than 100 miles of agricultural levees exist in the floodplain. Major tributaries between the Fulton and Keokuk stations are the Wapsipinicon, Rock, Iowa, and Skunk Rivers.

L&D 26. The reach of the UMR between Keokuk and L&D 26 is characterized by a series of six pools maintained by the operation of locks and dams, wing dams, closing dams, and dredging. More than 117 miles of levees exist in the floodplain. As the lowest of the pooled reaches of the UMR main stem, this area is characterized by a wide floodplain that has been extensively altered by levee construction behind which lies extensive agricultural lands. The river has a relatively small area of side channels and backwaters, and an extensive area of main channel border waters. Commercial navigation is comparatively high in this area, and this is the only pooled reach of the Mississippi River that regularly experiences year-round navigation. This reach has reduced its cross-sectional area significantly since construction and maintenance of the 9-foot navigation channel. Major tributaries in this reach include the Des Moines and Illinois Rivers.

Thebes. The reach between L&D 26 and Thebes differs from the upper reaches in that there is only one lock and dam, L&D 27, located in the Chain of Rocks Canal. The dam is similar to a low-level closing dam and cannot be regulated. Therefore, this pool is essentially free flowing. The 9-foot channel is maintained in this reach by closing structures, dikes, and revetments that constrict the flow to the main channel. The river has thus been greatly constricted and adjacent lands extensively leveed for agricultural use. The floodplain itself is dominated by agricultural land and woody vegetation, with a comparatively low percentage of water area. Extensive wing dam and revetment structures and levees have been constructed to maintain navigation and protect agricultural and urban land uses in the floodplain. Major tributaries entering this reach are the Missouri, Meramec, Kaskaskia, and Big Muddy Rivers.

Illinois River Stations

The Illinois River originates at the confluence of the Des Plaines and Kankakee Rivers. Since the turn of the century, its flows have been augmented with diversions from Lake Michigan. The northern basin drains a heavily industrialized area, and contributing tributaries are the Fox, Des Plaines, and Kankakee Rivers which extend the watershed to Wisconsin and Indiana. Major tributaries in the middle and lower reaches are the Spoon, Mackinaw, Sangamon, and LaMoine Rivers below Peoria and before Valley City. Approximately 75 percent of the river basin is in Illinois. Seven locks and dams on the river provide for commercial navigation. The basin's surficial geology comprises mostly glacial-drift and moraine deposits overlying dolomite, limestone, shale, and coal (National Water Summary, 1990-1991, p. 257).

The flow between Peoria, Valley City, and Hardin becomes more confined to a main channel. Land uses in this reach are cropland with pasture, woodland, forest, and urban area (Peoria). Valley City is located at RM 61.4 and Hardin is at RM 21.6. River miles on the Illinois River start from the river's confluence with the Mississippi River at Grafton.

Background hydrologic information on all six sampling stations is given in table 5.

Table 5. Hydrologic and Land Use Information for each Sampling Station

Location	*Drainage area*	*Major land uses*	*Average flow, cms*
Fulton	85,600 mi^2	Cropland	1,360
Keokuk	119,000 mi^2	Cropland	1,828
Grafton (L&D 26)	171,300 mi^2	Cropland	2,876
Thebes	712,300 mi^2	Cropland	5,610
Valley City	26,743 mi^2	Cropland, uiban	626
Hardin	28,690 mi^2	Cropland, urban	672*

Note: *Estimated by augmenting flow at Valley City with increased drainage area.

Land Uses

Most of the UMR states — Minnesota, Wisconsin, Iowa, Illinois, and Missouri — are known for their agriculture, forests, pastures, and livestock. Corn, soybeans, and wheat are the predominant crops. Table 6 illustrates the distribution of different land uses in the whole basin.

Table 6. Major Land Uses (in thousands of acres) by Tributary River Basin

River basin	*Total water area*	*Total land area*	*Urban & suburbs*	*Cropland & pasture*	*Forest*	*Other*
Mississippi Headwater	1,171	16,844	838	7,038	7,610	1,458
Chippewa and Black	203	8,271	273	3,370	4,228	400
Wisconsin	331	7,946	327	3,200	3,908	511
Rock	162	9,407	395	7,682	840	490
Illinois	249	18,916	1,580	14,793	1,460	1,083
Kaskaskia	47	4,626	297	3,372	697	260
Big Muddy	57	1,958	105	1,155	554	144
Meramec	52	4,652	205	1,961	2,351	135
Salt	28	2,974	82	2,155	623	114
Fox, Wyaconda, Fabius	17	2,005	58	1,543	320	84
Des Moines	57	9,453	384	8074	690	305
Skunk	13	2,989	132	2506	281	70
Iowa-Cedar	41	8,192	365	7156	400	271
Turkey, Maquoketa, Wapsipinicon, Upper Iowa	63	5,677	205	4621	694	157
Cannon, Zumbra, Root	49	3,705	151	2,810	616	128
Minnesota	249	10,580	340	9,277	346	617
Total area	2,789	118,195	5,737	80,613	25,618	6,227
Percentage of total land area			4.8	68.2	21.7	5.3

Source: Upper Mississippi River Comprehensive Basin Study Coordinating Committee (1970)

It can be seen that land used for crop and pasture accounts for more than 50 percent of the total. More importantly, more than 50 percent of the agricultural land is for com and soybeans, for which raw crop practices are used by many farmers. Farms growing corn and soybeans and using raw crop practices produce more sediment erosion and more nitrate and total phosphorous than farms growing other crops.

Groundwater

In the UMR and ILWW (Illinois River Waterway), the porous alluvial sediments underlying the floodplain and main channel provide substantial storage capacity for water and allow the stored groundwater to interact freely with the water in the river channel. In low flow or dry seasons when the ground-water table is higher, water drains out of the alluvium and sustains the flow in the river. When river flows are faster and stages are higher than the ground-water table in the alluvium, water from the river infiltrates the alluvium along with dissolved pollutants.

Ground-water conditions in upland areas also affect recharging processes in rivers and valleys. Rainfall that exceeds the infiltration capacity of the soil will either run off the land surface or accumulate in local depressions until removed by infiltration or evaporation. Groundwater may migrate to river valleys and eventually discharge to rivers at low flows. The groundwater moves slowly compared to the surface water, and distance between uplands and river valleys implies that the effects of groundwater on river water quality will not show immediately. Since upland areas are much larger than the floodplain area, the total volume of groundwater flowing from the uplands over time is important in replenishing the alluvial valley aquifers and maintaining flow in the rivers between rains (SAST, 1994).

Ground-water quality and surface water quality are interrelated. The quality of groundwater is determined by precipitation quality, the mineral and chemical composition of the soil, and the quality of surface water that seeps to groundwater. In turn, the quality of groundwater can affect the quality of surface water by draining back into the river during low flow periods.

The 1993 Flood

Unprecedented rainfalls occurred in the UMR region during 1993. The timing, location, and duration of these heavy rainfalls were the primary causes of the significant hydrometeorologic flood event. Many reports (e.g., Bhowmik, 1994; SAST, 1994) have detailed the causes and extent of the 1993 flood. Summarizing these reports, it can be concluded that spring snowmelt and preflood rainfalls *saturated the ground;* snowmelt and preflood rainfalls also *swelled many tributaries* to above normal seasonal levels before the flood; *intensive and prolonged rainfalls* between June and August were concentrated on the central region of the UMR; and *significant runoff from uplands* to small and then major tributaries subsequently flooded the main stem of the river.

Overall, the 1993 flood had the following characteristics:

- record breaking stages
- sequential rainfalls that produced multiple peaks at many locations
- prolonged flood duration
- extended and prolonged area of flooding, including floodplains and levee districts.

These characteristics and associated physical processes, such as soil erosion, and inundation of chemical plants could be potential impacts to water quality in the rivers.

Climate

The distribution of precipitation for 1993 is shown in figure 2. It can be seen that the highest rainfall amounts were centered around the Illinois border. Figure 3 further illustrates how the precipitation in the intensive period of 1993 compares to normal precipitation. Table 7 shows the historical ranking of 1993 precipitation in the five UMR states.

Table 7. Precipitation for States along the UMR, 1993

State	*Precipitation (inches)*	*Rank since 1895*
Iowa	47.55	wettest year
Illinois	50.05	wettest year
Missouri	54.73	3rd wettest year
Minnesota	32.21	6th wettest year
Wisconsin	35.12	22nd wettest year

Peak Stages

On the Mississippi River, from the Quad Cities area in Iowa and Illinois to below St. Louis, MO, the flood broke records set by the major floods of 1973 and 1965. In some areas, the stage was 6.3 feet higher than the highest level previously recorded. Overall, every gaging station on the Mississippi River below L&D 15 to Thebes, IL, experienced a new flood of record. Above L&D 15, the 1993 flood was surpassed by only one other event, the 1965 flood.

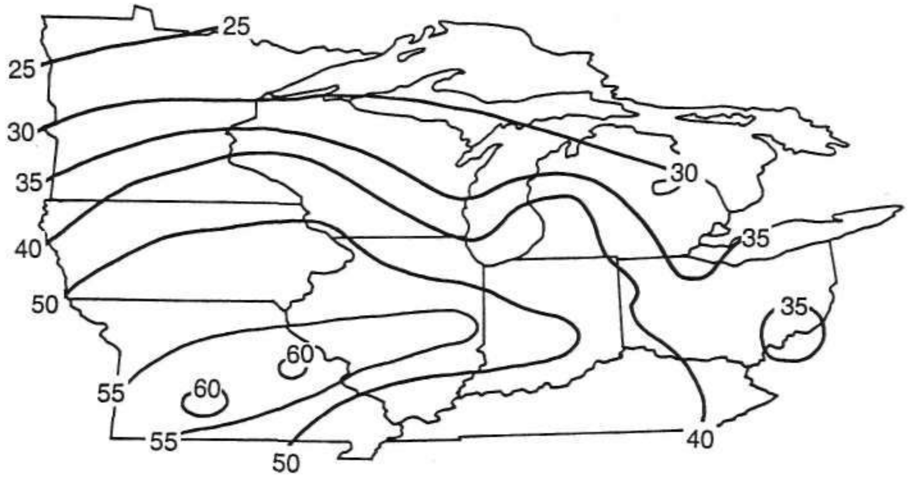

Figure 2. Annual Precipitation in the Midwest, 1993
(After Wendland and Dennison, 1993)

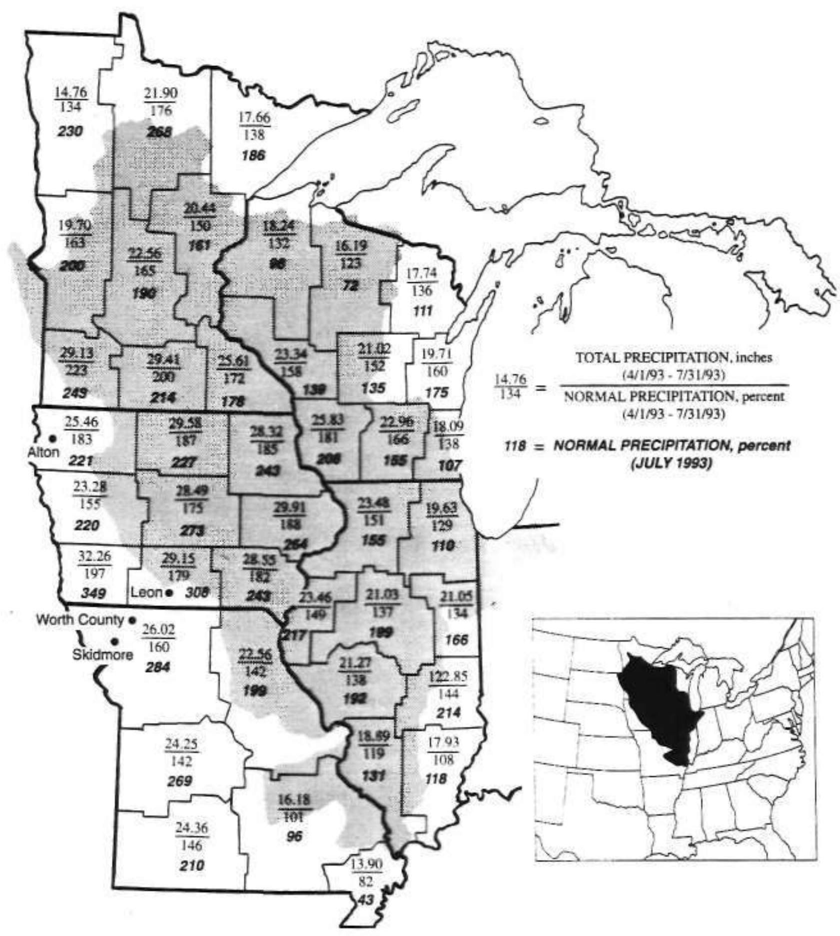

Figure 3. Precipitation in the Upper Mississippi River Basin,
April 1-July 31, 1993 (After ISWS, 1993)

Table 8 illustrates how high the peak stages were at each sampling station, the dates of the peak stages, and the days the rivers were above flood stage at each station. The stage differences and distances (river miles given in table 1) indicate the slope and flow velocities between stations on the Mississippi River, while the high stage on the Illinois River was mostly caused by backwater from the Mississippi River.

Table 8 Peak Stages (in feet) at Sampling Stations

Location	*Flood stage*	*Peak stage*	*Date*	*Ranking*	*Days above flood stage*
Fulton	578.68	585.66	7/8/93	2nd highest	82[1]
Keokuk	493.41	504.99	7/10/93	highest	171[2]
Grafton	421.79	441.79	8/1/93	highest	202
Thebes	333.00	345.51	8/7/93	highest	167
Valley City	432.00	444.90	8/1/93	3rd highest	N/A
Hardin	425.00	442.4	8/3/93	highest	N/A

Note: [1]At Camanche, IA. [2]At Quincy, DL [3]At Meredosia, IL.

Peak Discharges

Table 9 compares the 1993 mean flow and peak flow to the long-term average flow at each sampling station. The yearly discharge is presented by water year (WY). Water year T is defined from October 1 of year T-l to September 30 of year T.

Table 9. Long-Term Average Daily Discharge and 1993 Peak and Average Daily Flow at Sampling Stations (in cms)

Location	*Average flow*[1]	*1993 mean flow*	*1993 peak flow*[2]
Clinton	1,360	11,986	6,744
Keokuk	1,828	4,605	12,298
Grafton[3]	2,876	7,104	16,889
Thebes	5,611	12,638	27,713
Valley City	627	1,326	2,618
Hardin[4]	672	N/A	N/A

Notes: [1]Historical data through WY 1992. [2]USGS data (1994).
[3]Present discharge at L&D 26. [4]Stage recording station only.

It can be seen that the 1993 mean flows were about two to ten times and 1993 peak flows were about five to ten times the historical mean flows.

Sediment Transport

Changes in sediment loads can indicate the degree of soil erosion in a watershed and in the channels. Suspended sediment load is generally easier to measure, hence it is used here for this purpose. Bed load, on the other hand, generally is more difficult to measure. However, it can be reasonably assumed to be proportional to suspended load, generally 10 to 20 percent; the percentage may change dramatically during flood events, however. Table 10 lists the 1993 and long-term sediment transport scenario.

Table 10. Monthly Suspended Sediment Loads (in tons), 1993 and Long-Term Average

Location	*Long-term mean monthly loads*	*1993 mean monthly loads*	*1993 peak*	*Month*
East Dubuque[1]	330,933	554,240	1,327,439	July
Keokuk[1]	910,040	2,807,255	9,800,130	July
Thebes[2]	8,578,200	18,277,750	23,777,000	December
Valley City[2]	480,700	449,250	936,200	November

Notes: [1]From USACOE 1994. (Data from 1968-1992 were used for mean values.)
[2]From USGS (personal communication). (Data from 1983-1992 were used for Thebes and from 1981-1992 for Valley City.)

It can be seen that the mean monthly sediment load increased two- to threefold in 1993 for stations on the UMR while the peak monthly loads were four to ten times higher than the mean monthly loads. On the other hand, sediment transport on the Illinois River was not as significant as that on the UMR because the flood was caused by backwater effects during 1993. The peak months were also different for the two rivers.

Transport of Agricultural Chemicals

Very large amounts of pesticides (approximately 80 percent herbicides, 20 percent insecticides, and a small amount of fungicides) and fertilizers (mostly nitrogen) are applied on croplands in the UMR and ILWW basins. Herbicides and nitrogen from point and nonpoint sources can be transported into the rivers in runoff from agricultural and urban areas, discharge from groundwater, and atmospheric deposition. High concentrations of herbicides can occur in storm runoff. For small tributaries, chemical transport by runoff can occur from several weeks to several months following application, generally from April to June. On larger rivers, the concentration peaks are not as obvious and the duration is more spread out. Goolsby, Battaglin, and Thurman (1993) conducted a survey of the transport of agricultural chemicals during the 1993 flood between July and August. They found that during the 1993 flood, concentrations of agricultural chemicals were similar to those measured at the same time of year in 1991; however, the loads being transported were much larger due to the much larger flows. Table 11 lists the concentrations and loads of selected herbicides and nitrogen (Goolsby et al, 1993).

Table 11. Concentrations and Loads of Selected Herbicides and Nitrogen, July and August 1993

	Mean concentration				*Maximum daily loads*			
	Unit	*Fulton*	*Thebes*	*Valley City*	*Unit*	*Fulton*	*Thebes*	*Valley City*
Alachlor	µg/L	0.26	0.32	0.10	kg/d	180	780	
Atrazine	µg/L	1.4	2.64	2.48	kg/d	780	6,240	350
Cyanazine	µg/L	1.31	1.45	1.37	kg/d	750	4,180	
Metolachlor	µg/L	0.61	1.00	0.80	kg/d	380	2,400	
Nitrate-Nitrogen	mg/L	2.39	2.01	3.04	tons/d	1,495	5,205	553

Study Period

The data collection ran from December 1993 to June 1994. In order to give a proper perspective of the background information, the climate, agricultural activities, flows, and sediment data during that period are described briefly here.

Climate

Table 12 lists total monthly precipitation for 1993 and 1994 (data were provided by Dr. Kenneth Kunkel, Illinois State Water Survey).

Table 12a. Monthly Precipitation (inches) for the UMR Basin above Keokuk

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
1993	1.21	0.67	2.07	3.68	4.95	7.71	6.77	5.82	3.14	1.08	1.53	0.66
1994	1.19	1.16	0.51	3.62	1.82	5.00	4.53	4.08	4.31	2.13	2.25	0.79

Table 12b. Monthly Precipitation (inches) for the Illinois Basin above Hardin

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
1993	3.40	1.68	3.59	4.65	2.61	8.28	6.85	5.15	7.42	2.51	2.75	0.77
1994	1.34	2.91	0.93	5.72	1.89	3.66	2.77	3.80	1.90	1.74	5.76	2.23

Table 12c Monthly Precipitation (inches) for the UMR Basin above Cairo

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
1993	1.59	1.01	2.09	3.62	4.71	7.24	8.29	4.72	5.04	1.38	2.00	0.81
1994	1.07	1.38	0.64	4.97	1.92	4.53	4.19	3.65	3.21	2.40	3.13	1.17

Cairo, IL, is located at the most downstream reach of the UMR. It can be seen that heavy rain fell in June 1994 above Keokuk at the end of the study period, while heavy rain fell in April 1994 on areas above the Illinois stations and extended to Cairo.

Discharges

Table 13 lists the monthly mean discharge for WY 1993 and 1994, and historical data at the sampling stations. Values during the study period are in boldface for easy identification.

Table 13. Monthly Mean Discharge (cms) at Sampling Stations

	Valley City			*Fulton*			*Keokuk*		
	1993	*1994*	*Avg*	*1993*	*1994*	*Avg*	*1993*	*1994*	*Avg*
Oct	290	1,554	391	1,231	1,586	1,153	1,529	2,623	1,449
Nov	978	1,095	541	1,674	1,428	1,096	2,758	1,937	1,423
Dec	1,065	**1,036**	841	1,302	**1,252**	774	2,519	**1,659**	1,059
Jan	1,687	**543**	656	1,079	**1,068**	716	2,046	**1,353**	998
Feb	1,103	**754**	686	948	**1,361**	775	1,541	**2,023**	1,165
Mar	1,457	**1,182**	1,145	1,504	**2,112**	1,419	3,548	**3,324**	2,247
Apr	2,001	**1,302**	1,187	4,333	**2,397**	2,518	7,087	**2,793**	3,357
May	1,439	**1,089**	1,004	3,916	**3,001**	2,295	6,169	**3,383**	2,985
Jun	970	**557**	888	3,998	**1,542**	1,934	5,948	**2,065**	2,582
Jul	1,723	489	703	5,636	1,826	1,570	10,932	2,431	1,988
Aug	1,414	307	547	3,213	1,368	1,061	6,319	1,748	1,327
Sept	1,782	222	519	2,455	1,650	1,074	4,627	1,759	1,310

	L&D26			*Thebes*		
	1993	*1994*	*Avg*	*1993*	*1994*	*Avg*
Oct	1,9453	5,721	1,893	3,913	12,137	4,104
Nov	4,472	3,964	2,048	7,523	8,801	4,310
Dec	4,814	**3,228**	1,864	9,844	**6,736**	3,944
Jan	4,562	**2,234**	1,855	9,167	**4,367**	3,801
Feb	3,219	**2,760**	2,278	6,829	**5,713**	4,493
Mar	5,962	**4,293**	3,937	10,941	**8,637**	7,076
Apr	9,694	**5,086**	5,432	15,818	**11,097**	9,328
May	9,445	**5,205**	4,957	16,149	**11,323**	8,728
Jun	6,920	**3,140**	4,021	12,190	**6,648**	7,790
Jul	13,298	3,457	3,213	21,692	6,039	6,646
Aug	11,814	2,341	1,975	21,763	3,956	4,348
Sept	8,782	2,155	1,862	15,282	3,488	4,087

It can be seen that during 1993 major flooding began in April and peaked in July, then gradually tapered off until December. When the project started in December 1993, flows were still higher than historical means and gradually approached historical means in March or April for the stations. Figure 4 contains the daily discharge plots for the study period at all six stations.

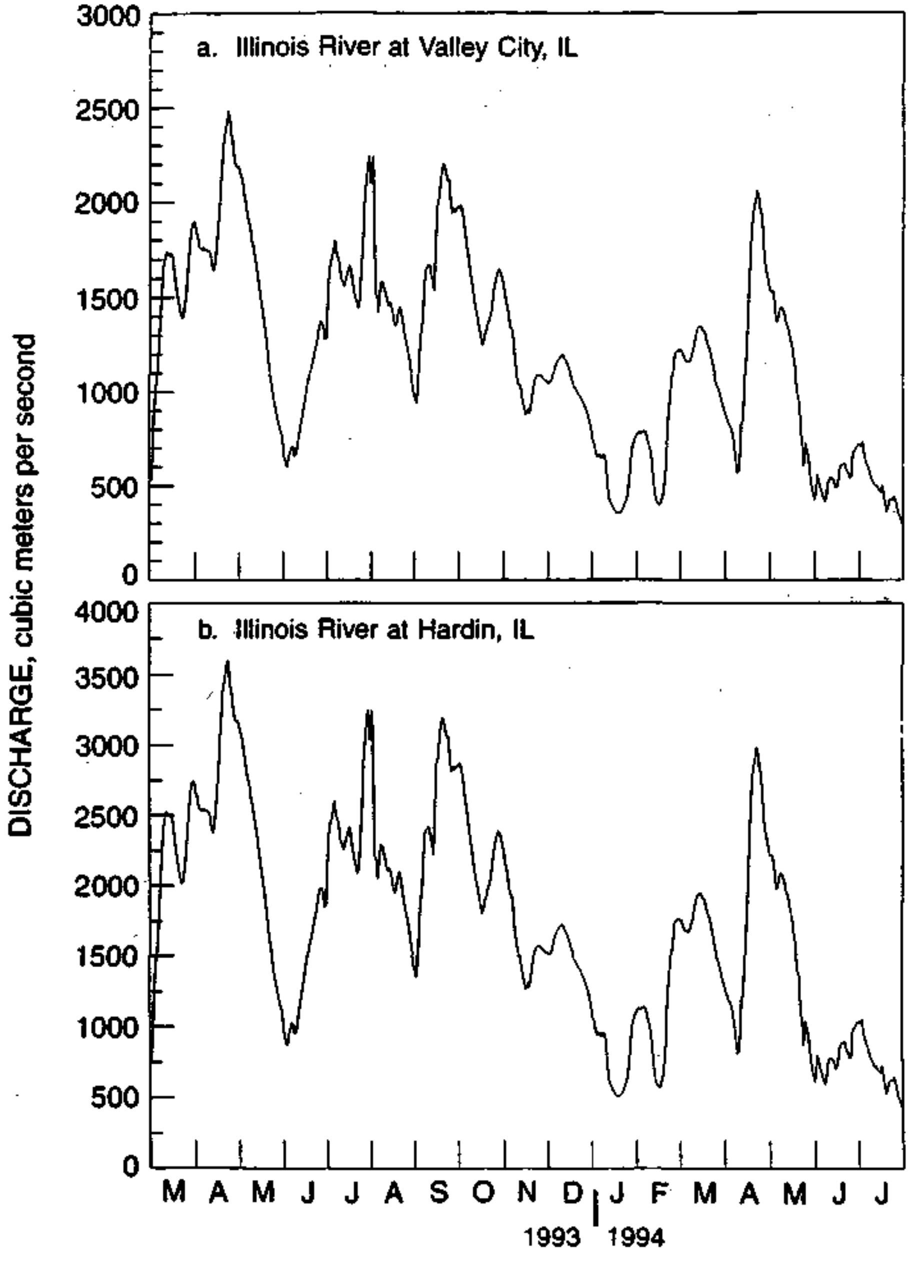

Figure 4. Daily Discharges at each Sampling Station for the 1993 Flood (March 1993-November 1993) and the Study Period (December 1993-July 1994)

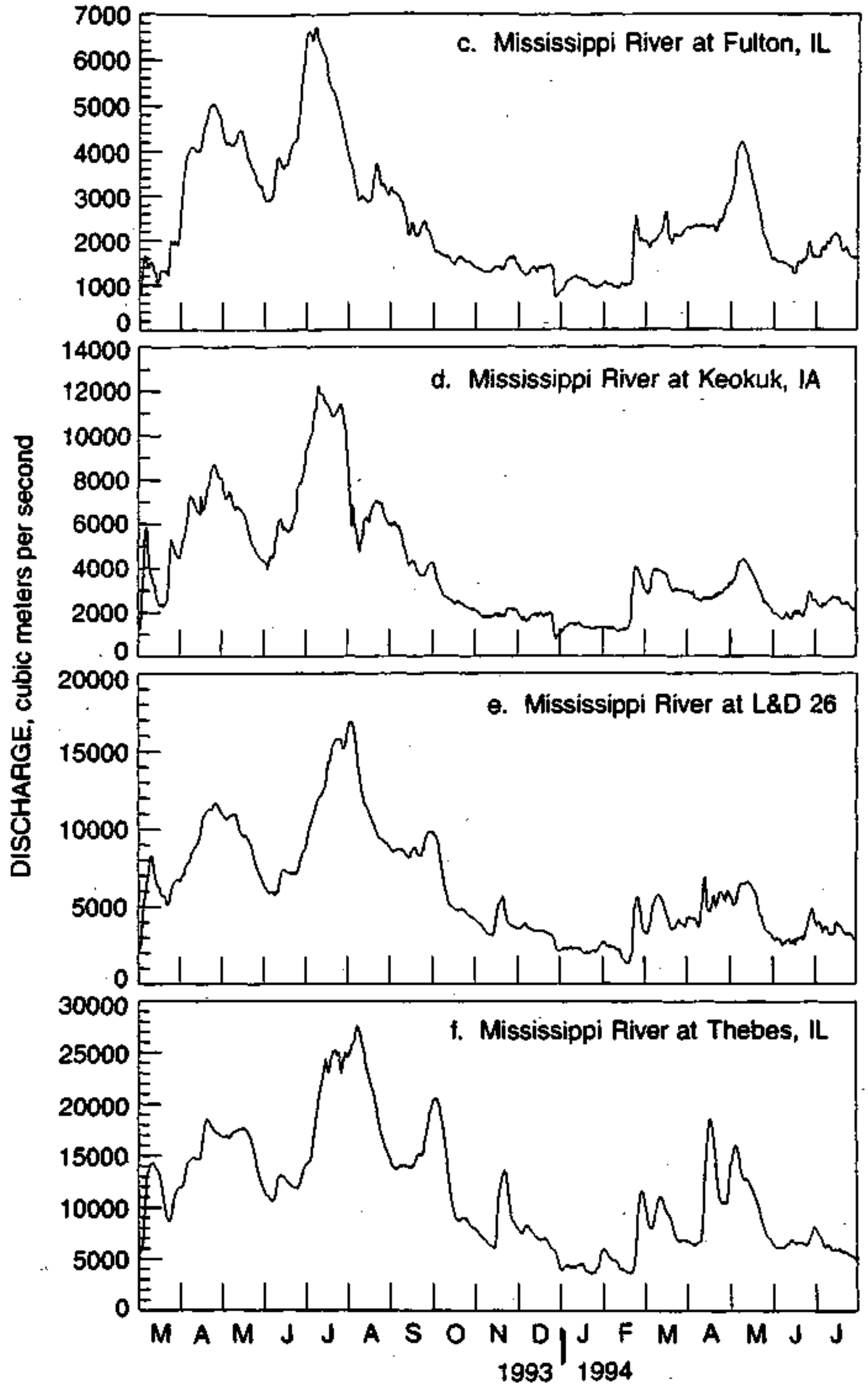

Figure 4. (Concluded)

Suspended Sediment Concentrations

Table 14 shows the mean monthly sediment loads at Valley City and Thebes respectively. Values in boldface occurred during the study period.

Table 14. Monthly Mean Sediment Loads (tons/day), Illinois River

	Valley City			Thebes		
	1993	1994	Avg	1993	1994	Avg
Oct	2,170	15,400	8,537	85,100	281,000	172,456
Nov	31,200	13,900	14,929	75,2000	242,000	223,911
Dec	16,700	**9,850**	19,008	76,7000	**93,200**	385,171
Jan	16,800	**8,960**	8,247	432,000	**65,000**	149,275
Feb	6,290	**27,200**	15,971	217,000	**179,000**	205,630
Mar	20,300	**12,800**	25,375	777,000	**313,000**	445,233
Apr	10,800	**43,500**	22,212	102,000	**446,000**	554,000
May	11,300	**23,400**	24,438	645,000	**363,000**	577,250
Jun	23,400	**14,100**	27,875	710,000	**216,000**	511,790
Jul	10,800	9,110	16,572	982,000	173,000	318,150
Aug	6,340	2,320	7,723	541,000	42,000	134,900
Sept	23,600	1,290	8,577	383,000	28,700	174,550

It can be seen that sediment transport in the Illinois River near Valley City was generally lower than historical means, except during April 1994. On the Mississippi River near Thebes, on the other hand, tremendous sediment transport occurred during the 1993 flood, particularly between March and August 1993. Overall, sediment transport during the study period was below historical means.

Application of Herbicides

Table 15a gives the estimated annual use of selected herbicides in the UMR basin, and table 15b shows the estimated load at Thebes for these herbicides during a one-year study.

Table 15a. Estimated Annual Use of Selected Herbicides in the UMR Basin (in metric tons)

	alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	simazine	triflurzlin
UMRS	12,200	13,400	4,160	6,210	11,000	611	174	5,440

Table 15b. Estimated Herbicide Loads at Thebes, April 1991 - March 1992 (in metric tons)

	alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	simazine	triflurzlin
Thebes	47.9	291	1.27	126	107	5.06	13.7	0.51

Ambient Water Quality Conditions in the ILWW and UMR

Antecedent water quality conditions at river reaches represented by the selected sampling stations are briefly reviewed. An IEPA water quality report (1994) indicated that a wide variety of waterborne toxins are monitored in Illinois rivers and streams. Copper, cadmium, lead, mercury, silver, and zinc all exceeded the state's general use standards. No organic compounds were considered to be elevated. In stream sediments, elevated concentrations of arsenic, chromium, copper, lead, mercury, zinc, cadmium, chlordane, DDT, dieldrin, heptachlor epoxide, and PCBs were identified.

However, overall stream water quality has steadily improved over the last 24 years. There are reported downward trends in metals concentrations and other conventional pollutants. The relationship between improving trends in DO, COD, and total ammonia is consistent with the continued decline of point source impacts. Upward trends in total phosphorus and nitrite/nitrate concentrations have been identified in some basins, likely the result of contributions from nonpoint pollution sources. Information presented in table 16 is summarized from an IEPA water quality report (1994).

Table 16. Waterbody Information for Sampling Sites

Site	*Overall use support*	*Causes*	*Sources*
Valley City	Partial support	Siltation, nutrients, flow alteration	Agriculture, hydrologic modification, channelization, flow regulation
Hardin	Partial support	Siltation, nutrients, flow alteration	Agriculture, hydrologic modification, channelization, flow regulation
Fulton	Full support		
Keokuk	Partial support	Siltation, nutrients, flow alteration, other habitat alterations	Agriculture, hydraulic/habitat modification
L&D 26	Partial support/minor impairment	Priority organics, siltation, other habitat alterations, suspended solid nutrients	Municipal point sources, agriculture, hydrology/habitat modification
Thebes	Partial support/ moderate impairment	Pesticides, metals, siltation, other habitat alterations, nutrients	Industrial point sources, municipal point sources, agriculture, urban storm sewer runoff, hydrologic/ habitat modification

RESULTS

This chapter presents data collected for this project. These data were retrieved from the IEPA STORET database. In the process, agency code 21ILAMB was used for retrieving all CORE1 parameters, 21ILL was used for all PEST1 parameters, and 21BLSED was used for CORE3 and CORE4 parameters. During the study period, IEPA staff also collected water quality data on their regular sampling schedule. These data are also included in the report.

The tables in this section present lab results for each parameter in time sequence; discharge information is presented in the second column following the date. There are occasions when a value was stopped in the system because it may not have represented the actual measured value or the content was below the detection limit of the equipment and could not be quantified. For all those values, a "K" is used as a remark code that stands for "off-scale low" — the actual values are not known, but are lower than the values shown. A dash (-) is used in the tables to indicate data that are not available from STORET.

Water Quality

CORE1 Parameters

Tables 17a-f list all CORE1 parameters for each station. Stations on each river are arranged in order from upstream to downstream. It can be seen that many inorganic elements were below detection limits during the study period. Cyanide was below the detection limit for all sites; arsenic was below the detection limit everywhere except at Valley City on 2/15/94 and at Thebes on 5/4/94; phenol was below the detection limit at all sites except at Valley City on 3/29/94 and at L&D 26 on 3/8/94 and 3/29/94; and mercury was below the detection limits everywhere except at Keokuk on 6/1/94. Total acidity data are mostly not available from STORET except for one count from February 1994, and that value is below the detection limit.

Among parameters that showed detectable values, arsenic, cyanide, and mercury are normally considered toxic at low concentrations; while phenol, fluoride, chloride, and sulfate can affect aesthetic conditions such as color, taste, and odor, render the water unfit for use, or produce deleterious health effects when their concentrations become significantly high.

Table 17a. C0RE1 Results, Valley City

Date	Q (cms>	Cyanide (mg/L)	Arsenic (µg/L)	Phenol (µg/L)	Fluoride (mg/L)	Mercury (µg/L)	Chloride (mg/L)	Sulfate (mg/L)	Tot. Acid. (mg/L)	Alka. (mg/L)	TKN (mg/L)
12/15/93	1,109	.010K	1K	10K	0.23	.05K	36	74	-	214	0.94
12/22/93	976	.010K	1K	10K	0.27	.05K	32	74	-	246	0.29
1/5/94	659	.010K	1K	10K	0.26	.05K	41	58	-	256	1.33
1/25/94	538	.010K	1K	10K	0.35	.05K	58	91	-	264	1.4
2/15/94	396	.010K	2	10K	0.27	.05K	110	58	IK	192	2.2
3/8/94	1,177	.010K	1K	10K	0.22	.05K	81	54	-	170	1.45
3/29/94	971	.010K	1K	17	0.24	.05K	69	67	-	208	1.3
4/19/94	1,893	0.01	1K	10K	0.21	.05K	28	42	-	127	1.5
5/12/94	1,353	.010K	1K	10K	0.25	.05K	39	59	-	205	1.4
6/1/94	467	.010K	1K	10K	0.28	.05K	47	68	-	221	1.7
6/22/94	577	.010K	1	.O1K	0.42	.05K	67	82	-	181	1.27

Table 17b. **CORE1 Results, Hardin**

Date	Q (cms)	Cyanide (mg/L)	Arsenic (µg/L)	Phenol (µg/L)	Fluoride (mg/L)	Mercury (µg/L)	Chloride (mg/L)	Sulfate (mg/L)	Tot. Acid. (mg/L)	Alka. (mg/L)	TKN (mg/l)
12/7/93	1,691	-	-	-	-	.05K	-	-	-	-	-
12/16/93	1,560	.010K	1K	10K	0.24	.05K	33	72	-	216	0.91
1/5/94	954	.010K	1K	10K	0.25	.05K	41	57	-	252	1.33
1/25/94	778	.010K	1K	10K	0.29	.05K	50	84	-	263	0.87
2/15/94	573	.010K	1K	10K	0.26	.05K	107.	57	IK	193	1.8
3/8/94	1,703	.010K	1K	10K	0.22	.05K	80	54	-	163	1.42
3/29/94	1,404	.010K	1K	10K	0.25	.05K	66	68		-	0.93
4/19/94	2,739	0.02	1K	10K	0.2	.05K	25	40	-	127	1.6
5/12/94	1,957	.010K	1K	10K	0.24	.05K	36	56	-	196	1.5
6/2/94	807	.010K	1K	10K	0.27	.05K	44	66	-	214	1.4
6/22/94	835	.010K	1	.O1K	0.41	.05K	67	80	-	188	0.76

Table 17c CORE1 Results, Fulton

Date	Q (cms)	Cyanide (mg/L)	Arsenic (µg/L)	Phenol (µg/L)	Fluoride (mg/L)	Mercury (µg/L)	Chloride (mg/L)	Sulfate (mg/L)	Tot. Acid. (mg/L)	Alka. (mg/L)	TKN (mg/L)
12/13/93	1,279	.010K	1K	10K	0.13	.05K	14	99	IK	171	0.71
3/28/94	2,173	.010K	1K	10K	0.16	.05K	15	32	-	146	1.4
5/23/94	2,190	.005K	5K	5K	0.14	.05K	15	45	-	160	1.7
6/21/94	1,576	.010K	1K	.O1K	0.12	.05K	14	52	-	156	0.84

Table 17d. CORE1 Results, Keokuk

Date	Q (cms)	Cyanide (mg/L)	Arsenic (µg/L)	Phenol (µg/L)	Fluoride (mg/L)	Mercury (µg/L)	Chloride (mg/L)	Sulfate (mg/L)	Tot. Acid. (mg/L)	Alka. (mg/L)	TKN (mg/L)
12/14/93	1,757	.010K	1K	10K	0.14	.05K	21	47	-	186	0.55
12/28/93	874	.010K	1K	10K	0.17	.05K	21	48	-	212	0.38
1/4/94	1,344	.010K	1K	10K	0.15	.05K	23	36	-	206	1.37
1/24/94	1,274	.010K	1K	10K	0.18	.05K	23	44	-	208	.10K
2/14/94	1,225	.010K	1K	10K	0.17	.05K	21	30	1K	202	0.85
3/7/94	3,792	.010K	1K	10K	0.17	.05K	18	28	-	151	1.86
3/28/94	3,000	.010K	1K	10K	0.16	.05K	21	30	-	163	1.3
4/18/94	2,553	0.01	1K	10K	0.15	.05K	17	47	-	127	.10K
5/11/94	4,387	.010K	1K	10K	0.13	.05K	15	36	-	127	1.4
6/1/94	1,973	.010K	1K	10K	0.2	0.06	16	53	-	158	1.6
6/21/94	1,842	.010K	1K	.O1K	0.2	.05K	18	50	-	156	0.52

Table 17c CORE1 Results, L&D 26

Date	*Q (cms)*	*Cyanide (mg/L)*	*Arsenic (µg/L)*	*Phenol (µg/L)*	*Fluoride (mg/L)*	*Mercury (µg/L)*	*Chloride (mg/L)*	*Sulfate (mg/L)*	*Tot. Acid. (mg/L)*	*Alka. (mg/L)*	*TKN (mg/L)*
12/16/93	3,400e*	.010K	1K	10K	0.2	.05K	21	50	-	182	0.72
1/6/94	2,324e	.010K	1K	10K	0.18	.05K	25	38	-	207	1.24
1/25/94	2,069e	.010K	1K	10K	0.23	.05K	36	62	-	236	0.93
2/15/94	1,400	.010K	1K	10K	0.2	.05K	39	43	1K	202	1.2
3/8/94	5,299	.010K	1K	26	0.16	.05K	19	33	-	137	1.76
3/29/94	3,826	.010K	1K	10	0.18	.05K	22	32	-	162	1.2
4/19/94	5,724	.010K	1K	10K	0.16	.05K	18	42	-	120	2.2
5/12/94	6,461	.010K	1K	10K	0.15	.05K	16	36	-	136	1.3
6/2/94	2,763	.010K	1K	10K	0.19	.05K	19	52	-	159	1.5
6/22/94	2,834	.010K	1K	.01K	0.25	.05K	24	56	-	156	0.48

*Note: e represents estimated value.

Table 17f. CORE1 Results, Thebes

Date	*Q (cms)*	*Cyanide (mg/L)*	*Arsenic (µg/L)*	*Phenol (µg/L)*	*Fluoride (mg/L)*	*Mercury (µg/L)*	*Chloride (mg/L)*	*Sulfate (mg/L)*	*Tot. Acid. (mg/L)*	*Alka. (mg/L)*	*TKN (mg/L)*
12/17/93	6,934	.010K	1K	10K	0.23	.05K	24	78	-	178	0.47
1/6/94	4,188	.010K	-	10K	0.23	0.05	30	68	-	193	1.1
3/17/94	9,452	.010K	1K	10K	0.19	.05K	26	53	-	150	1.66
3/30/94	6,820	.010K	1K	10K	0.22	.05K	30	63	-	165	1.1
5/4/94	16,131	.010K	2	10K	0.16	-	15	42	-	103	1.7
6/23/94	6,368	.010K	1K	.01K	0.26	.05K	20	76	-	134	0.63

IEPA (1994) has set different standards for designated uses. Table 18 lists the specified "general use" standard for selected C0RE1 parameters.

Table 18. General Use Standards for Selected CORE1 Parameters

Parameter	*Standard*	*Parameter*	*Standard*
arsenic[1]	360 µg/L	*phenol*	100 ug/L
cyanide[1]	22 mg/L	*fluoride*	1.4 mg/L
mercury	0.2 ug/L	*chloride*	500 mg/L
		sulfate	500 mg/L

Note: [1]Acute standard is used for this parameter.

It can be seen that parameters having detectable values in tables 17a-f are below the specified standard.

PEST1 Parameters

PEST1 constituents are further divided into two categories: PEST1 and CORE2. Generally, all constituents belong to four groups: triazine herbicides, chlorophenoxy herbicides, organochlorine insecticides, and organophosphate insecticides. Since pesticides are synthetic chemicals that do not occur naturally, their appearance is the result of their use, disposal, or manufacture.

PEST1 contains triazine and chlorophenoxy herbicides such as.alachlor, atrazine, butylate, cyanazine, metolachlor, metribuzin, and trifluralin; organophosphate insecticides such as chloropyrifos, diazinon, fonofos, malathion, methyl parathion, phorate and terbufos; and captan, a fungicide. CORE2 contains organochlorine insecticides such as aldrin, dieldrin, DDT, DDE, and DDD groups, chlordane, endrin, chlordane trans isomer, methoxychlor, gamma BHC lindane, hexachlorobenzene, pentachlorophenol, chlordane cis isomer, and PCBs; and organophosphate insecticides such as nonachlor cis isomer, nonachlor trans isomer, and hexachlorocylehexane.

Among these groups, organochlorine insecticides are generally characterized by great persistence in the natural environment, low solubility in water, and a strong tendency to adsorb to particulate matter in soil, water, and bed sediment. Applications of organochlorine insecticides have declined dramatically since the restrictions and bans imposed by the USEPA during the mid- to late 1970s.

Results for PEST1 parameters are listed in Appendix A, while results for CORE2 parameters are listed in Appendix B. As shown in tables A-l through A-6, most of the parameters are below reporting limits. These include butylate, captan, chloropyrifos, diazinon, fonofos, malathion, methyl parathion, metribuzin, terbufos, and trifluralin. Data for phorate are not available. Four PEST1 parameters, including alachlor, atrazine, cyanazine, and metolachlor had detectable values, and their concentrations decreased from April 1994 to June 1994. Alachlor and atrazine are of particular concern to USEPA for their effects on water taken out of the rivers for drinking purposes. Concentrations of the four parameters in the rivers correspond to the timing of applications, rainfall, and surface runoff.

Atrazine and cyanazine had higher concentrations on both rivers followed by metolachlor and alachlor. The Illinois River stations had higher concentrations of atrazine and cyanazine than the Mississippi River stations, and their ranges were higher than those given in table 11. Of the two stations on the Illinois River, Hardin had higher atrazine, cyanazine, and metolachlor concentrations than Valley City; concentrations of alachlor were similar.

On the other hand, herbicide concentrations were lower at Fulton and Keokuk, higher at L&D 26, and lower at Thebes. This may be because the two upstream stations drain areas with less cropland than L&D 26. Detectable levels of atrazine, cyanazine, metolachlor, and alachlor at L&D 26 corresponded more often to those at Hardin than those at Keokuk. Atrazine and cyanazine were each detected only once at Thebes, in June 1994. Their values were much lower than those observed during July and August 1993 (see table 11).

For CORE2 parameters, almost all constituents were less than the specified detection limit except for pentachlorophenol on March 8, 1994, at both Valley City and Hardin; on March 28, 1994, at Fulton; and on December 17, 1993, at Thebes.

The established standards for pesticides in natural water are listed in table 19 below.

Table 19. Standards for Selected PEST1 Parameters

Parameter	*Standard*	*Parameter*	*Standard*
alachlor[1]	2 µg/L	cyanazine[2]	1 µg/L
atrazine[1]	3 µg/L	metolachlor[2]	100 µg/L

Notes: [1]Maximum contaminant level (USEPA, 1992).
[2]Health advisory level (USEPA, 1992).

Sediment Quality

Sediment samples served as a screening device to detect the presence of pollutants or bioaccumulative chemicals that are not readily detected by routine water quality analyses (Kelly and Hite, 1984). The usual sources of contaminants in sediment are point sources such as industrial and municipal wastewater. Because sediment characteristics are directly related to aquatic habitat and diversity, analysis of stream sediment is useful to understand the extent to which human activity influences the aquatic environment.

Kelly and Hite (1984) observed that the most elevated sediment concentrations were generally found in the Des Plaines River basin in northeastern Illinois, where a multitude of discharges occur in association with the Chicago metropolitan area. The Des Plaines River (a tributary to the Illinois River) and sections of the Illinois River contained high concentrations of several constituents.

CORE3 Parameters

CORE3 data available from STORET at the time this report was finalized are from the week of December 13, 1993. Values of these parameters are listed in table 20, which shows that all available parameters on the Mississippi River were below detection limits. The situation is similar on the Illinois River except that p,p'DDE had detectable values at both Valley City and Hardin; PCBs, aldrin, dieldrin, p,p'DDD, and endrin, all organochlorine compounds, showed up at Valley City. The constituents that had detectable values at Valley

City did not show up at Hardin, which differs from the pattern in water quality samples.

Table 20. CORE3 Results (in µg/kg)

Parameter	*Valley City*	*Hardin*	*Fulton*	*Keokuk*	*L&D 26*	*Thebes*
PCBs	39	10.00K	10.00K	10.00K	10.00K	10.00K
Aldrin	29	1.00K	1.00K	1.00K	1.00K	1.00K
Dieldrin	5.1	1.00K	1	1.00K	1.00K	1.00K
Total DDT	10.00K	10.00K	10.00K	10.00K	10.00K	10.00K
o, p DDE	-	-	-	-	-	-
p,p' DDE	3.1	1.2	1.00K	1.00K	1.00K	1.00K
o.p DDD	-	-	-	-	-	-
p.p' DDD	2.3	1.00K	1.00K	1.00K	1.00K	1.00K
O.P DDT	-	-	-	-	-	-
p.p' DDT	1.00K	1.00K	1.00K	1.00K	1.00K	1.00K
Total Chlordane	5.00K	5.00K	5.00K	5.00K	5.00K	5.00K
Chlordane cis isomer	2.00K	2.00K	2.00K	2.00K	2.00K	2.00K
Chlordane trans isomer	2.00K	2.00K	2.00K	2.00K	2.00K	2.00K
Nonachlor cis isomer	-	-	-	-	-	-
Nonachlor trans isomer	-	-	-	-	-	-
Endrin	2.1	1.00K	1.00K	1.00K	1.00K	1.00K
Methoxychlor	5.00K	5.00K	5.00K	5.00K	5.00K	5.00K
Hexachlorocyclohexane-alpha BHC	1.00K	1.00K	1.00K	1.00K	1.00K	1.00K
Gamma BHC-Lindane	1.00K	1.00K	1.00K	1.00K	1.00K	1.00K
Hexachlorobenzene	LOOK	1.00K	1.00K	1.00K	1.00K	1.00K
Pentachlorophenol	-	-	-	-	-	-
Heptachlor	1.00K	1.00K	1.00K	1.00K	1.00K	1.00K
Heptachlor epoxide	1.00K	1.00K	1.00K	1.00K	1.00K	1.00K
Lindane	-	-	-	-	-	-

Note: Data from the week of December 13, 1993. K indicates off-scale low values.

Currently there are no standards for sediment concentration. For reference purposes, the background Illinois sediment constituent concentrations (table 21) collected between 1974 and 1980 (Kelly and Hite, 1984) can be used. Note, however, that more than 60 percent of all background sites were located in the Big Muddy, Kaskaskia, and Sangamon River basins.

Table 21. Background Illinois Stream Sediment Concentrations (in ug/kg) for Selected CORE3 Parameters

Chlordane	*Total DDT*	*DDT*	*Dieldrin*	*Heptachlor poxide*	*PCBs*
<5.0	<5.0	<2.21	<4.30	<1.25	<2.96

Source: Kelly and Hite (1984).

On the basis of this information, the measured PCBs at Valley City were much higher than the background means.

CORE4 Parameters

C0RE4 parameters consist of two groups: nutrients (total volatile residues, TKN, total phosphorus, and COD) and metals (arsenic and eight other constituents.) Their results are presented in tables 22a-f. These data showed that, in general, the concentrations of arsenic and metals were similar at these stations on both the Illinois and Mississippi Rivers. Some differences existed in the nutrient concentrations, however. Valley City had much higher COD than Hardin; similarly, Fulton had much higher COD than Keokuk, L&D 26, and Thebes. The COD concentrations at Fulton and Valley City were comparable, however. Similar observations can be found for total volatile residues, TKN, and total phosphorus. Kelly and Hite (1984) found that total volatile residues, COD, and TKN are highly correlated. They also found that COD, along with other nutrients and metals, would return to background levels generally at distances greater than five miles downstream of metropolitan wastewater treatment plants.

Table 22a. CORE4 Results, Valley City

Date	*Q, cms*	*T. Volatile percent*	*TKN*	*T. Phosphorus*	*COD*	*Arsenic*	*Cadmium*	*Chromium*
12/15/93	1,109	5.3	3,333	838	44,800	3.6	1	17
3/29/94	971	4.0	1,428	638	-	4.6	1.0K	17
6/21/94	617	4.8	2,390	620	-	3.7	1.0K	12

Date	*Q, cms*	*Copper*	*Iron*	*Lead*	*Manganese*	*Mercury*	*Zinc*
12/15/93	1,109	17.0	17,000	17	765	.1K	84
3/29/94	971	15.0	18,000	28	617	1.0K	77
6/21/94	617	11.0	14,000	15	526	.1K	46

Note: Units = mg/kg unless otherwise specified. K indicates off-scale low values.

Table 22b. CORE4 Results, Hardin

Date	*Q, cms*	*T. Volatile percent*	*TKN*	*T. Phosphorus*	*COD*	*Arsenic*	*Cadmium*	*Chromium*
12/16/93	1,560	3.8	1,205	597	19,900	6.8	1.0K	17
3/28/94	1,445	4.4	1,379	722	-	5.2	1.0K	21
6/22/94	835	5.8	5.60K	544	-	4.0	1.0K	17

Date	*Q, cms*	*Copper*	*Iron*	*Lead*	*Manganese*	*Mercury*	*Zinc*
12/16/93	1,560	17.0	19,000	16	617	.1K	58
3/28/94	1,445	21.0	19,000	25	833	1.0K	99
6/22/94	835	15.0	19,000	16	826	.1K	64

Note: Units = mg/kg unless otherwise specified. K indicates off-scale low values.

Table 22c C0RE4 Results, Fulton

Date	Q, cms	T. Volatile percent	TKN	T. Phosphorus	COD	Arsenic	Cadmium	Chromium
12/13/93	1,279	4.5	2,550	585	39,600	4.1	1.0K	15
3/28/94	2,173	3.3	3,286	452	-	2.9	1.0K	10
6/21/94	1,576	3.2	105	401	-	2.5	1.0K	9

Date	Qcms	Copper	Iron	Lead	Manganese	Mercury	Zinc
12/13/93	1,279	11.0	15,000	12	822	.1K	55
3/28/94	2,173	8.0	12,000	12	657	0.1	41
6/21/94	1,576	6.0	11,000	10.0K	555	.1K	35

Note: Units = mg/kg unless otherwise specified. K indicates off-scale low values.

Table 22d. CORE4 Results, Keokuk

Date	Q, cms	T. Volatile percent	TKN	T. Phosphorus	COD	Arsenic	Cadmium	Chromium
12/14/93	1,757	1.6	307	208	13,650	2.5	1.0K	3
3/28/94	3,000	4.5	1,594	949	-	4.0	1.0K	16
6/21/94	1,842	6.5	145	791	-	3.5	1.0K	15

Date	Q, cms	Copper	Iron	Lead	Manganese	Mercury	Zinc
12/14/93	1,757	1.0	4,500	10.0K	255	.1K	9
3/28/94	3,000	14.0	17,000	17	793	1.0K	65
6/21/94	1,842	12.0	15,000	13	756	.1K	59

Note: Units = mg/kg unless otherwise specified. K indicates off-scale low values.

Table 22e. CORE4 Results, L & D 26

Date	Q, cms	T. Volatile percent	TKN	T. Phosphorus	COD	Arsenic	Cadmium	Chromium
12/16/93	3,400e	1.0	45.K	109	2,800	1.4	1.0K	4
3/29/94	3,826	3.5	174	430	-	3.8	1.0K	13
6/22/94	2,834	3.7	5.3K	433	-	5.3	1.0K	10

Date	Q, cms	Copper	Iron	Lead	Manganese	Mercury	Zinc
12/16/93	3,400e	1.0	5,000	10.0K	95	.1K	10
3/29/94	3,826	10.0	14,000	16	481	1.0K	45
6/22/94	2,834	7.0	11,000	10.0K	433	.1K	31

Note: Units = mg/kg unless otherwise specified. K indicates off-scale low values; e indicates estimated value.

Table 22f. CORE4 Results, Thebes

Date	*Q, cms*	*T. Volatile Percent*	*TKN*	*T. Phosphorus*	*COD*	*Arsenic*	*Cadmium*	*Chromium*
12/17/93	6,934	1.0	40.	265	5,750	2.9	1.0K	3
3/30/94	6,820	3.0	1,032	444	-	5.0	l.OK	13
6/23/94	6,368	8.7	6.2K	683	-	2.9	l.OK	16

Date	*Q, cms*	*Copper*	*Iron*	*Lead*	*Manganese*	*Mercury*	*Zinc*
12/17/93	6,934	l.OK	4,200	10.0K	78	.1K	14
3/30/94	6,820	11.0	14,000	15	553	l.OK	49
6/23/94	6,368	18.0	19,000	21	1,000	.1K	69

Note: Units = mg/kg unless otherwise specified. K indicates off-scale low values.

Again, the background means measured by Kelly and Hite (table 23) were used as a reference for examining the study values.

Table 23. Background Illinois Stream Sediment Concentrations (in mg/kg) for Selected CORE4 Parameters

T. Volatile percent	*TKN*	*Tot. Phosphorus*	*COD*	*Arsenic*	*Cadmium*
4.44	1,380	506	49,091	5.16	<0.53

Chromium	*Copper*	*Iron*	*Lead*	*Manganese*	*Mercury*	*Zinc*
9.78	14.9	13,345	16.7	736	0.042	50.3

Source: Kelly and Hite (1984)

The higher concentrations measured at Valley City and Fulton were still close to these background means. However, chromium appeared to be higher than the background mean measured during 1974 to 1980 at all stations.

Temperature, pH, DO, and Conductivity

The pH of a natural river is a useful index of the status of equilibrium reactions in which the water participates. Natural pH is 7 at 25°C, lower than 7 at temperatures above 25°C, and higher at temperatures below 25°C. IEPA (1994) specifies the minimum and maximum pH values for general use water as 6.5 and 9.0 standard units (SU), respectively, and for secondary contact and indigenous aquatic life as 6.0 and 9.0 SU, respectively.

In rivers the DO concentration primarily depends on temperature, which varies with season and climate; other factors, such as atmospheric pressure and concentrations of other solutes can also determine the DO in water. In the absence of substances that cause its depletion, the DO concentration in stream water approximates the saturation level for oxygen in water in contact with the atmosphere and decreases with increasing water temperature from about 14 mg/L at freezing to about 7 mg/L at 30°C (Smith et al., 1993). IEPA (1994) specifies the minimum DO concentration for general use water as 5 mg/L and for secondary contact and indigenous aquatic life as 4 mg/L.

Conductivity is a measure of the ion concentration in natural water. Its reporting unit, µS/cm (micro-siemens per centimeter at 25°C), suggests that conductivity varies with temperature and discharge.

Tables 24a-f list the field measurements for these parameters. From these tables one can see that higher pH concentrations were observed in winter, while lower DO was measured in summer at all stations. The DO values on the Illinois River, however, were lower than IEPA specifications for secondary contact. No direct cause could be found to explain these low values. However, a post-flood boom in zebra mussels in the Illinois River reported by the Illinois Natural History Survey may have contributed to the lower DO values.

Table 24a. Measured Temperature, pH, DO, and Conductivity at Valley City

Date	*Q, cms*	*Temp. (°C)*	*pH*	*DO (mg/L)*	*Cond. (µS/cm)*
12/16/93	1,078	4.3	9.1	12.5	230
1/5/94	659	1.6	8.5	-	738
1/25/94	538	0.6	9.3	12.1	771
2/15/94	396	1.4	-	13.2	-
3/8/94	1,177	6.0	7.9	10.4	701
3/28/94	999	9.2	8.3	9.6	757
4/18/94	1,769	14.4	8.1	7.2	461
5/13/94	1,339	17.0	8.3	9.8	640
6/2/94	558	23.2	8.0	6.9	702
6/22/94	577	30.5	7.9	3.5	736

Table 24b. Measured Temperature, pH, DO, and Conductivity at Hardin

Date	*Q, cms*	*Temp. (°C)*	*pH*	*DO (mg/L)*	*Cond. (µS/cm)*
12/16/93	1,560	4.2	8.5	12.7	635
1/5/94	954	1.3	8.8	-	721
1/25/94	778	0.2	8.9	12.7	743
2/15/94	573	1.6	-	13.9	-
3/8/94	1,703	5.5	8.0	10.2	688
3/28/94	1,445	9.5	8.3	8.9	748
4/18/94	2,559	14.6	8.0	6.6	441
5/13/94	1,937	17.1	8.1	8.5	613
6/2/94	807	22.7	7.7	4.0	667
6/22/94	835	30.3	7.5	1.3	746

Table 24c. Measured Temperature, pH, DO, and Conductivity at Fulton

Date	*Q, cms*	*Temp. (°C)*	*pH*	*DO (mg/L)*	*Cond. (µS/cm)*
12/13/93	1,279	0.7	8.8	16.0	440
3/28/94	2,173	6.0	-	-	-
6/21/94	1,576	28.0	7.9	4.8	456

Table 24d. Measured Temperature, pH, DO, and Conductivity at Keokuk

Date	*Q, cms*	*Temp. (°C)*	*pH*	*DO (mg/L)*	*Cond. (µS/cm)*
12/14/93	1,757	1.8	9.0	14.0	347
1/4/94	1,344	-	-	-	-
1/24/94	1,274	0.3	9.4	14.4	549
2/14/94	1,225	0.7			536
3/7/94	3,792	3.2	6.7	13.3	426
3/28/94	3,000	7.2	7.9	11.6	450
4/18/94	2,553	13.0	8.4	9.8	399
5/11/94	4,387	15.2	8.4	10.5	361
6/1/94	1,973	23.0	8.5	6.9	458
6/21/94	1,842	29.3	7.8	5.1	470

Table 24e. Measured Temperature, pH, DO, and Conductivity at L&D 26

Date	*Q, cms*	*Temp. (°C)*	*pH*	*DO (mg/L)*	*Cond. (µS/cm)*
12/16/93	3,400e*	3.6	8.1	15.0	515
1/6/94	2,324e	0.6	9.3	-	545
1/25/94	2,097e	0.2	8.6	15.0	634
2/15/94	1,400	1.1	-	15.9	614
3/8/94	5,299	3.7	8.0	10.9	411
3/29/94	3,826	8.0	8.5	10.6	458
4/18/94	5,724	14.1	8.8	10.5	379
5/11/94	6,461	16.7	8.0	8.8	376
6/2/94	2,763	22.7	8.4	7.6	446
6/21/94	2,834	29.6	7.8	5.9	501

Note: e represents an estimated value.

Table 24f. Measured Temperature, pH, DO, and Conductivity at Thebes

Date	*Q, cms*	*Temp. (°C)*	*pH*	*DO (mg/L)*	*Cond. (µS/cm)*
12/17/94	6,934	5.0	9.2	12.5	545
3/30/94	6,820	9.4	7.4	9.2	554
6/23/94	6,368	28.6	7.7	5.5	490

ANALYSES

On the basis of the results presented in the previous chapter, it can be observed that:

1. Most parameters surveyed during the post-flood period were below detection limits.
2. Of those water quality parameters showing detectable concentrations, no significant violations of established standards were found.

One conclusion that can be made is that no negative effects were found in the water quality parameters collected during this period from the Mississippi and Illinois Rivers. However, the effects from physical processes that occurred during the 1993 flood, such as sediment redistribution in the system and intensified infiltration to ground-water reservoirs in uplands or river valleys, will eventually show up in the post-flood water and sediment quality of these two rivers after releases from sediment or ground-water reservoirs.

Known features of the 1993 flood are its sequential rainfalls with multiple peaks at many locations, prolonged flood duration, and the extensive area of flooding, including floodplains and levee districts. It can be postulated that the two large rivers carried heavy loads of chemicals (especially in the span of rising stages), similar to those calculated by Rajagopal (1993). Hence the method of analysis would be to examine the concentrations or loads of selected parameters. However, it became evident that the loads were diluted by the tremendous discharges of the flood, so their concentrations were not significantly higher than those in nonflooding years, as surveyed by Goolsby et al. (1993) for selected agricultural chemicals.

When investigating the post-flood effects, it is reasonable to determine whether there are elevated or reduced levels of chemicals in the water and sediment, and to some extent, to try to explain them with physical processes. The methodology used here is to determine the deviation of the measured data from historical statistics or trends in the data. The examination will start with DO, pH, and conductivity of water and then proceed to seleted parameters.

Definition of Deviation from Mean

One advantage of these measured water and sediment parameters is that long-term data are available for many of them and can be retrieved from STORET. In the following discussion, *long-term data* are defined as all historical data available before the 1993 flood (i.e., before March 31, 1993), and *study period* covers the data collected between December 1, 1993, and June 30, 1994. STORET can provide statistics for the parameters, including the maximum, minimum, mean, and standard deviation. On the basis of these statistics, a deviation from long-term mean (DFM) is calculated as:

$$DFM = \frac{(Mean_{study\ period} - Mean_{longterm})}{Standard\ Deviation_{longterm}}$$

which shows if there is any significant deviation from the historical mean. In the following discussion, a mean concentration during the study period is said to be *significantly elevated or reduced* when the DFM is more than 3 (positive or negative) standard deviations from the long-term mean; *elevated or reduced* if the DFM is between 2 and 3 standard deviations from the long-term means; and *slightly elevated or reduced* if the DFM is between 1 and 2 standard deviations from the long-term mean.

DO, pH, **and** Conductivity

Comparison to Historical Data

Tables 25a-f contain the statistics for both study and long-term periods. The following observations can be made for the study period:

- Valley City: a new minimum conductivity was measured on 12/16/93; the mean pH was slightly elevated.
- Hardin: a new minimum DO was measured on 6/22/94; pH was slightly elevated.
- Fulton: DO had a new maximum on 12/13/93 and a new minimum on 6/21/94. Conductivity had a new maximum on 6/21/94.
- Keokuk: DO had a new minimum on 6/21/94, and pH had a new maximum on 1/24/94. Conductivity had a new maximum on 1/24/94 and new minimum on 12/14/93.
- L&D 26: pH had a new maximum on 1/6/94, while conductivity on average was slightly elevated.
- Thebes: pH had a new maximum on 12/17/93.

Table 25a. DO, pH, and Conductivity at Valley City

	DO, mg/L	*pH, su*	*Conduct, µm/cm*
Study period			
No. of samples	9	9	9
maximum	13.2	9.3	771
minimum	3.5	7.9	230
mean	9.5	8.4	637
DFM	0.229	1.379	-0.231
Long-term data			
No. of samples	124	197	136
maximum	14.20	9.80	1150
minimum	3.00	6.50	354.0
mean	8.90	7.81	669.5
stand. dev.	2.621	.428	140.8

Table 25b. DO, pH, and Conductivity at Hardin

	DO, mg/L	*pH, su*	*Conduct, fjm/cm*
Study period			
No. of samples	9	9	9
maximum	13.9	8.9	748
minimum	1.3	7.5	441
mean	9.4	8.3	667
DFM	0.257	1.445	0.024
Long-term data			
No. of samples	46	144	88
maximum	14.00	8.60	1100.0
minimum	4.00	6.60	315.0
mean	8.81	7.68	663.7
stand. dev,	2.297	.429	137.2

Table 25c DO, pH, and Conductivity at Fulton

	DO, mg/L	*pH, su*	*Conduct, fjm/cm*
Study period			
No. of samples	2	2	2
maximum	16.0	8.8	456
minimum	4.8	7.9	440
mean	10.6	8.35	448
DFM	0.030	0.649	2.090
Long-term data			
No. of samples	15	58	20
maximum	15.40	9.80	424.0
minimum	6.10	6.30	278.0
mean	10.5	7.95	354.1
stand. dev.	3.309	.616	44.93

Table 25d. DO, pH, and Conductivity at Keokuk

	DO, mg/L	*pH, su*	*Conduct, µm/cm*
Study period			
No. **of** samples	8	8	8
maximum	14.0	9.4	549
minimum	5.1	6.7	347
mean	10.2	8.3	444
DFM	-0.065	0.672	0.814
Long-term data			
No. **of** samples	15	44	15
maximum	15.2	8.90	472.0
minimum	7.10	6.50	348.0
mean	10.37	7.97	409.7
stand. dev.	2.631	.491	42.14

Table 25e. DO, pH, and Conductivity at L&D 26

	DO, mg/L	*pH, su*	*Conduct, µm/cm*
Study period			
No. **of** samples	9	9	9
maximum	15.9	9.30	634
minimum	5.9	7.81	411
mean	11.13	8.4	542
DFM	0.445	0.725	1.057
Long-term data			
No. **of** samples	148	154	151
maximum	19.00	8.90	670.0
minimum	2.60	7.30	281.0
mean	9.68	8.15	464.8
stand. dev.	3.257	.345	73.01

Table 25f. DO, pH, and Conductivity at Thebes

	DO, mg/L	*pH, su*	*Conduct, µm/cm*
Study Period			
No. **of** samples	3	3	3
maximum	12.5	9.2	554
minimum	5.5	7.4	490
mean	9.1	8.1	529.7
DFM	0.282	0.249	0.405
Long Term Data			
No. **of** samples	35	89	37
maximum	13.40	8.70	643.0
minimum	3.00	7.40	1.00
mean	8.36	8.06	483.03
stand. dev.	2.627	.269	115.3

Overall, the average pH over the study period was slightly elevated on the Illinois River. New maximum values for DO and pH were recorded at the beginning of the study period during winter months, while new minimum values were recorded toward the end of the study period during summer months. Conductivity, on the other hand, was elevated at the upstream station of the Mississippi River (Fulton) and slightly elevated at L&D 26 with new maximums at Fulton and Keokuk. At Fulton and Valley City new minimums were recorded, primarily during winter months.

Comparison to Monthly Data

pH. The pH of a natural river indicates the status of the equilibrium reactions in which the water participates. A natural pH value is 7 at 25°C, but it varies inversely with temperature. Therefore, one can expect to observe higher pH values in winter and lower pH values in summer. Figure 5 illustrates how the measured data compare to historical monthly maximum, mean, and minimum values at each station. Three stations on the Mississippi River (except Fulton) had new maximum pH values, and both stations on the Illinois River had slightly elevated average pH during the study period.

DO. Dissolved oxygen is essential to the respiration of aquatic organisms, and its concentration in streams is a major determinant of the species composition of biota in the water and underlying sediments. Moreover, the DO in streams has a profound effect on the biochemical reactions that occur in water and sediment, which in turn affect numerous aspects of water quality, including solubility of many toxic elements and aesthetic qualities of odor and taste (Hem, 1985). Figure 6 illustrates how the measured data compare to historical monthly maximum, mean, and minimum values for four stations. The seasonal pattern is well demonstrated at each station. At all stations, DO values appeared to be higher at the beginning (winter months) and decreased toward the end (summer months) of the study period, reflecting their dependency on temperature.

Several stations recorded new minimum DO concentrations. Atmospheric pressure and concentrations of other solutes can also be used to determine the DO in water. Low DO can be caused by processes that consume dissolved, suspended, or precipitated organic matter, such as the elevation of total ammonia nitrogen, TOC, and TKN. TKN over the study period was near or below the long-term means. In 1994, the Illinois Natural History Survey reported a massive increase of zebra mussels in the lower Illinois River. The boom in zebra mussels could be the major cause of low DO at Illinois stations.

Conductivity. Conductivity is a measure of the ion concentration in natural water. It varies proportionally to temperature and has demonstrated a fairly good linear relationship with dissolved solids at Gila River, Arizona (Hem, 1985). The linear relationship is particularly well

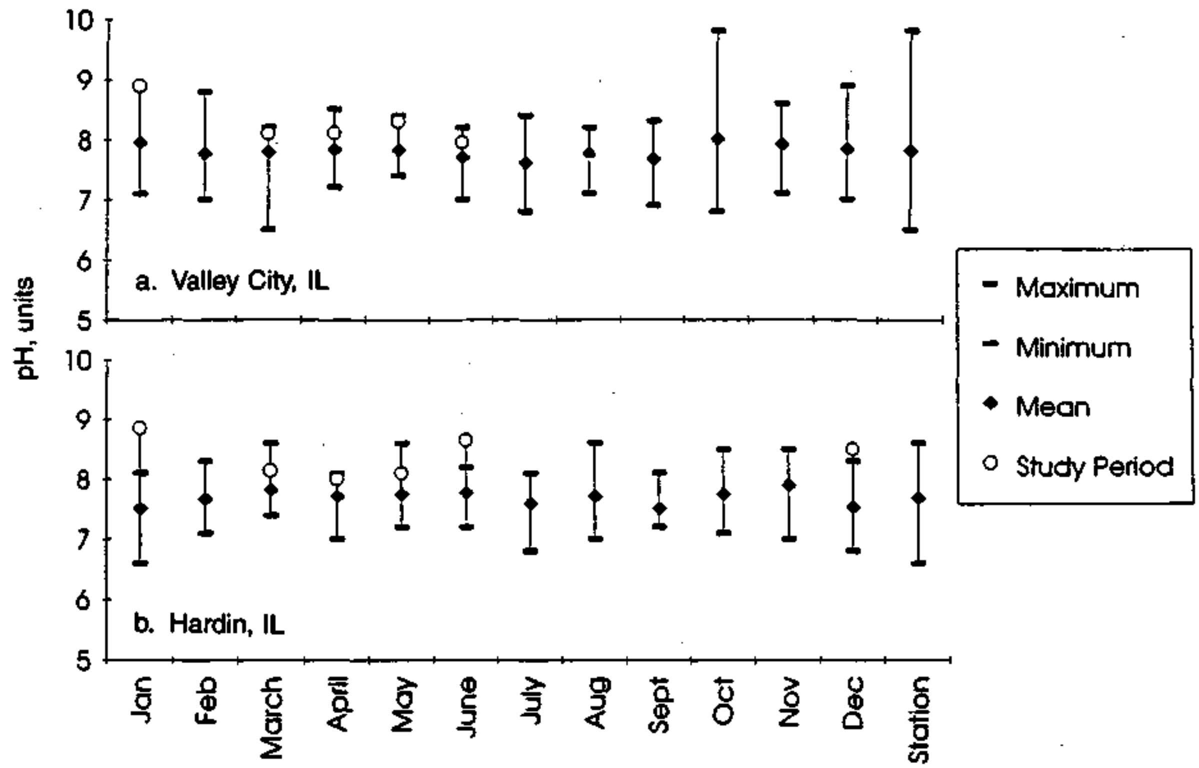

Figure 5. Comparison of the Mean Monthly pH Values during the Study Period to Historical Maximum, Mean, and Minimum Values at each Sampling Station

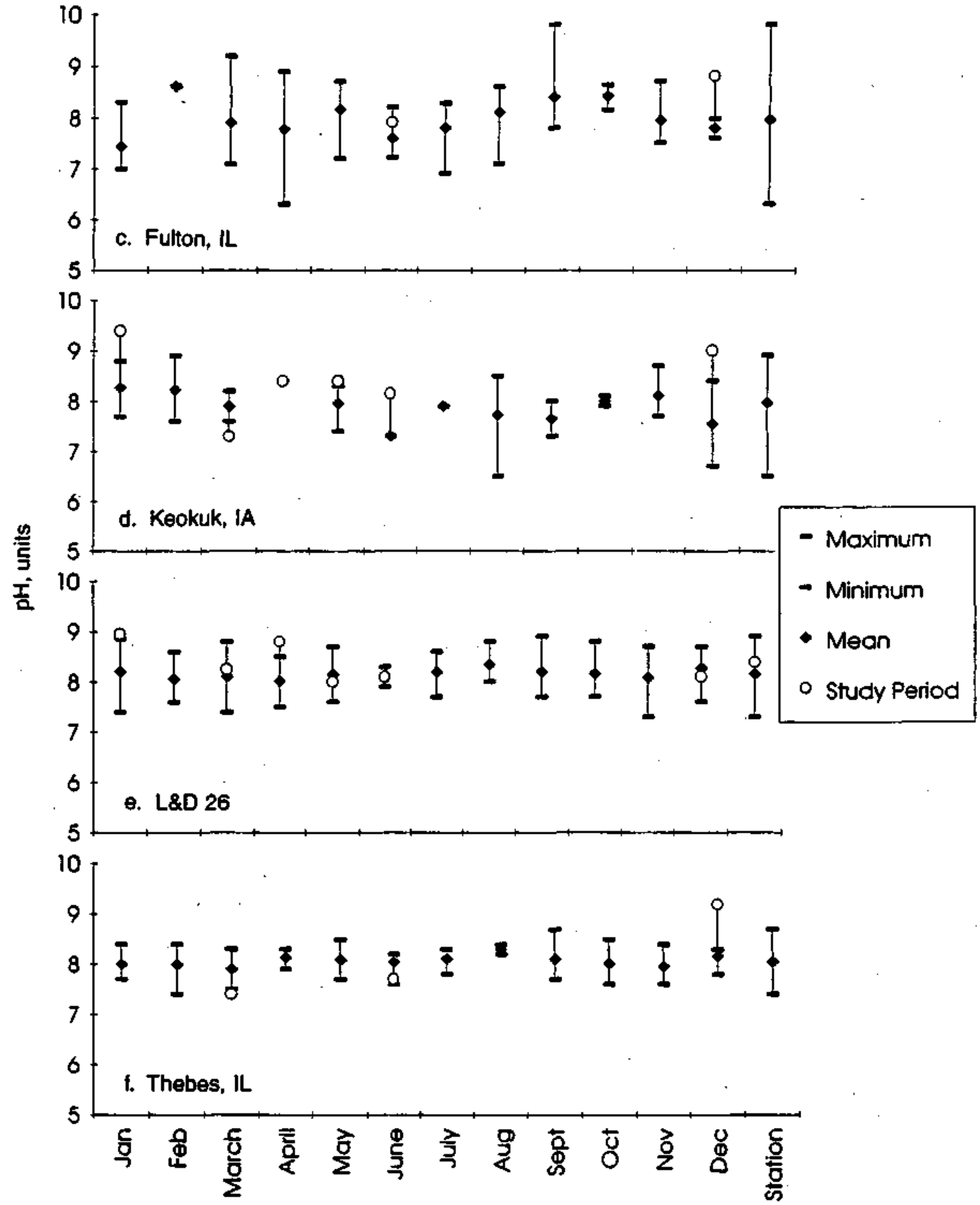

Figure 5. (Concluded)

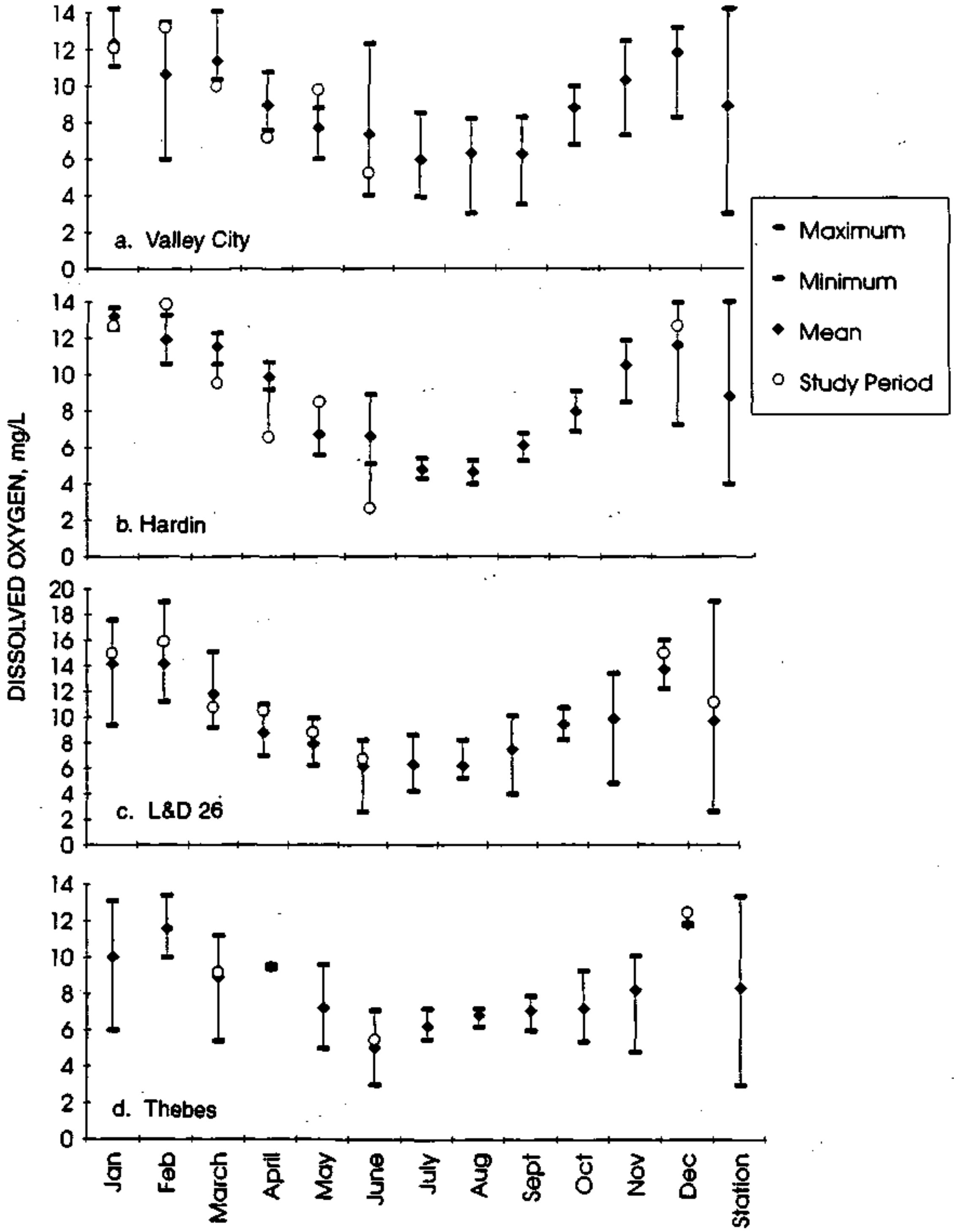

Figure 6. Comparison of the Mean Monthly DO Values during the Study Period to Historical Maximum, Mean, and Minimum Values at each Sampling Station

demonstrated by the concentrations of chloride and sulfate. On the Mississippi River, conductivity had new maximums at Fulton and Keokuk with elevated means at Fulton; sulfate concentrations (to be shown later) had a new maximum at Fulton and the mean value was significantly elevated, while the mean value was slightly elevated at Keokuk. On the basis of these results, it can reasonably be believed that a similar linear relationship exists on the Mississippi River. Moreover, conductivity will be a good indicator for ground-water analysis in any future detailed investigations of the effects from groundwater after the floods.

CORE1 Parameters

Comparison to Historical Data

When presenting CORE1 results, it was noted that only fluoride, chloride, sulfate, total alkalinity, and TKN had consistently detectable values. Concentrations for other parameters, including cyanide, arsenic, phenols, and mercury were mostly below detectable limits during the study period. On the other hand, it should be noted that all these parameters have historically had detectable values at these stations (except for Hardin, which has detectable arsenic and mercury only). If such reductions are caused by the 1993 flood, they should be counted among the impacts of the flood.

Tables 26a-e list statistics for fluoride, chloride, sulfate, total alkalinity, and TKN. One can observe the following about those parameters during the study period.

- Valley City: total alkalinity had a new maximum value, but all mean values stayed within one standard deviation from the long-term mean.
- Hardin: the total alkalinity had a new maximum value and TKN had a new minimum; otherwise the mean values stayed within one standard deviation from the long-term mean.
- Fulton: sulfate concentrations had a new maximum value. The mean sulfate concentration was also significantly elevated from the long-term mean.
- Keokuk: the mean value of sulfate was slightly elevated from the long-term mean, and TKN had a new minimum.
- L&D 26: total alkalinity had a new maximum value and TKN had a new minimum; otherwise, the mean values stayed within one standard deviation from the long-term mean.
- Thebes: there were no elevated concentrations at Thebes.

Table 26a. Statistics for Selected CORE1 Parameters at Valley City

	Fluoride mg/L	*Chloride mg/L*	*Sulfate mg/L*	*Tot.Alk mg/L*	*TKN mg/L*
Study period					
No. **of** samples	12	12	12	12	12
maximum	0.420	110.0	91.00	264.0	2.200
minimum	0.210	27.90	42.00	127.0	0.290
mean	0.277	55.44	66.08	204.3	1.304
DFM	-0.575	0.271	-0.552	0.647	-0.300
Long-term data					
No. **of** samples	94	172	191	135	185
maximum	0.940	120.00	130.0	253.0	4.500
minimum	0.150	0.000	11.00	90.00	0.150
mean	0.342	50.62	76.81	184.4	1.526
stand dev	.113	17.77	19.44	30.73	.739

Table 26b. Statistics for Selected CORE1 Parameters at Hardin

	Fluoride mg/L	***Chloride mg/L***	***Sulfate mg/L***	***Tot. Alk. mg/L***	***TKN mg/L***
Study period					
No. **of** samples	10	10	10	9	10
maximum	0.410	107.0	84.00	263.0	1.800
minimum	0.200	25.20	40.00	127.0	0.760
mean	0.263	55.02	63.40	201.3	1.252
DFM		-.205		.244	-.789
Long-term data					
No. **of** samples	-	6	-	5	5
maximum	-	122.0	-	252.0	2.100
minimum	-	26.00	-	116.0	1.100
mean	-	62.83	-	189.4	1.540
stand. dev.	-	38.13	-	48.89	.365

Table 26c Statistics for Selected CORE 1 Parameters at Fulton

	Fluoride mg/L	***Chloride mg/L***	***Sulfate mg/L***	***Tot. Alk mg/L***	***TKN mg/L***
Study period					
No. **of** samples	4	4	4	4	4
maximum	0.160	15.00	99.00	171.0	1.700
minimum	0.120	14.00	32.00	146.0	0.710
mean	0.138	14.50	57.00	158.3	1.163
DFM	-0.292	-0.062	3.615	0.526	-0.237
Long-term data					
No. of samples	52	60	60	48	60
maximum	0.330	39.00	52.00	272.0	3.200
minimum	0.050	8.600	17.00	100.0	0.300
mean	.152	14.77	27.57	144.0	1.291
stand. dev.	.048	4.337	8.141	27.18	.539

Table 26d. Statistics for Selected CORE1 Parameters at Keokuk

	Fluoride mg/L	*Chloride mg/L*	*Sulfate mg/L*	*Tot. Alk mg/L*	*TKN mg/L*
Study period					
No. of samples	12	12	12	12	12
maximum	0.200	23.20	53.00	212.0	1.860
minimum	0.130	14.80	28.00	127.0	0.380
mean	0.168	19.18	40.75	172.1	0.908
DFM	0.158	0.197	1.340	0.700	-0.423
Long-term data					
No. of samples	39	45	45	36	44
maximum	0.220	30.00	88.00	202.0	8.000
minimum	0.100	9.100	23.00	108.0	0.300
mean	0.162	18.28	33.22	156.5	1.402
stand. dev.	.038	4.564	5.62	22.30	1.168

Table 26e. Statistics for Selected CORE1 Parameters at L&D 26

	Fluoride mg/L	*Chloride mg/L*	*Sulfate mg/L*	*Tot. Alk mg/L*	*TKN mg/L*
Study period					
No. of samples	10	10	10	10	10
maximum	0.250	39.20	62.00	236.0	2.200
minimum	0.150	16.00	32.00	120.0	0.480
mean	0.190	23.89	44.40	169.7	1.253
DFM	-0.410	0.091	-0.002	0.522	-0.310
Long-term data					
No. of samples	19	143	143	134	137
maximum	0.500	49.00	78.00	223.0	7.000
minimum	0.120	8.100	15.00	100.0	0.500
mean	0.222	23.19	44.42	156.5	1.491
stand, dev.	.078	7.726	10.20	25.28	.767

Table 26f. Statistics for Selected CORE1 Parameters at Thebes

	Fluoride mg/L	*Chloride mg/L*	*Sulfate mg/L*	*Tot. Alk mg/L*	*TKN mg/L*
Study period					
No. of samples	7	7	7	7	7
maximum	0.300	30.10	78.00	193.0	1.700
minimum	0.160	15.40	42.00	103.0	0.470
mean	0.227	23.63	65.43	157.6	1.039
DFM	-0.449	0.382	-0.407	0.253	-0.437
Long-term data					
No. of samples	55	89	90	91	91
maximum	0.390	41.00	140.00	205.0	5.000
minimum	0.100	1.000	35.00	101.0	0.100
mean	0.258	21.39	74.78	151.7	1.350
stand. dev.	.069	5.856	22.95	23.25	.711

The new maximum concentrations of total alkalinity at Valley City, Hardin, and L&D 26 all occurred on 1/25/94, when the discharges at those stations were the second lowest during the sampling period. Fulton had the highest sulfate concentration on 12/13/93 when the discharge was the lowest during the period of collection. The occurrences of new maximums were mostly in winter at the end of the flood. Also, mean sulfate concentrations were significantly elevated at Fulton and slightly elevated at Keokuk during the study period. Comparisons of these data to discharges and to other stations are made as follows.

Comparison of Individual Data

Fluoride. Fluoride is present in most natural waters. Generally, its concentration is low, approximately less than 1.0 mg/L. Figure 7 compares the data at each station during the study period. The figure plots are arranged in order from upstream to downstream on each river, and the scale of concentration is the same on each plot. It can be seen that fluoride concentrations were all less than 1.0 mg/L, but they were higher and fluctuated more on the Illinois River than on the Mississippi River. The long-term mean at Valley City is 0.342 mg/L, approximately the same as the values measured at low discharges. Fluctuations varied conversely to the rising and falling of discharges on the Illinois River, indicating dilution by discharges. The flucuations were less on the Mississippi River, which is characteristic of large rivers. This is also evidenced by small standard deviations in historical data at the four Mississippi River stations.

The sources of fluoride generally are those mineral particles in sediments or in igneous and sedimentary rock. Groundwater can also contain fluoride concentrations exceeding 1.0 mg/L (Hem, 1985). There is no apparent decreasing or increasing trend for fluoride concentrations during the study period.

Chloride. Chloride is also a natural water chemical. Like fluoride, its concentration in natural water is generally low. However, exceptions occur where streams receive inflows of chloride-rich groundwater or industrial waste (Hem, 1985). Figure 8 presents the collected data for chloride. Chloride concentrations were higher and fluctuated more on the Illinois River than on the Mississippi River.

Because the chemical behavior of chloride is relatively stable unless its concentration is extremely high, and because it is not significantly adsorbed on mineral surfaces, chloride can be a good indicator of ground-water recharges. The concentration vs time plots showed a similar pattern on each river. There is also no apparent increasing or decreasing trend in chloride concentrations.

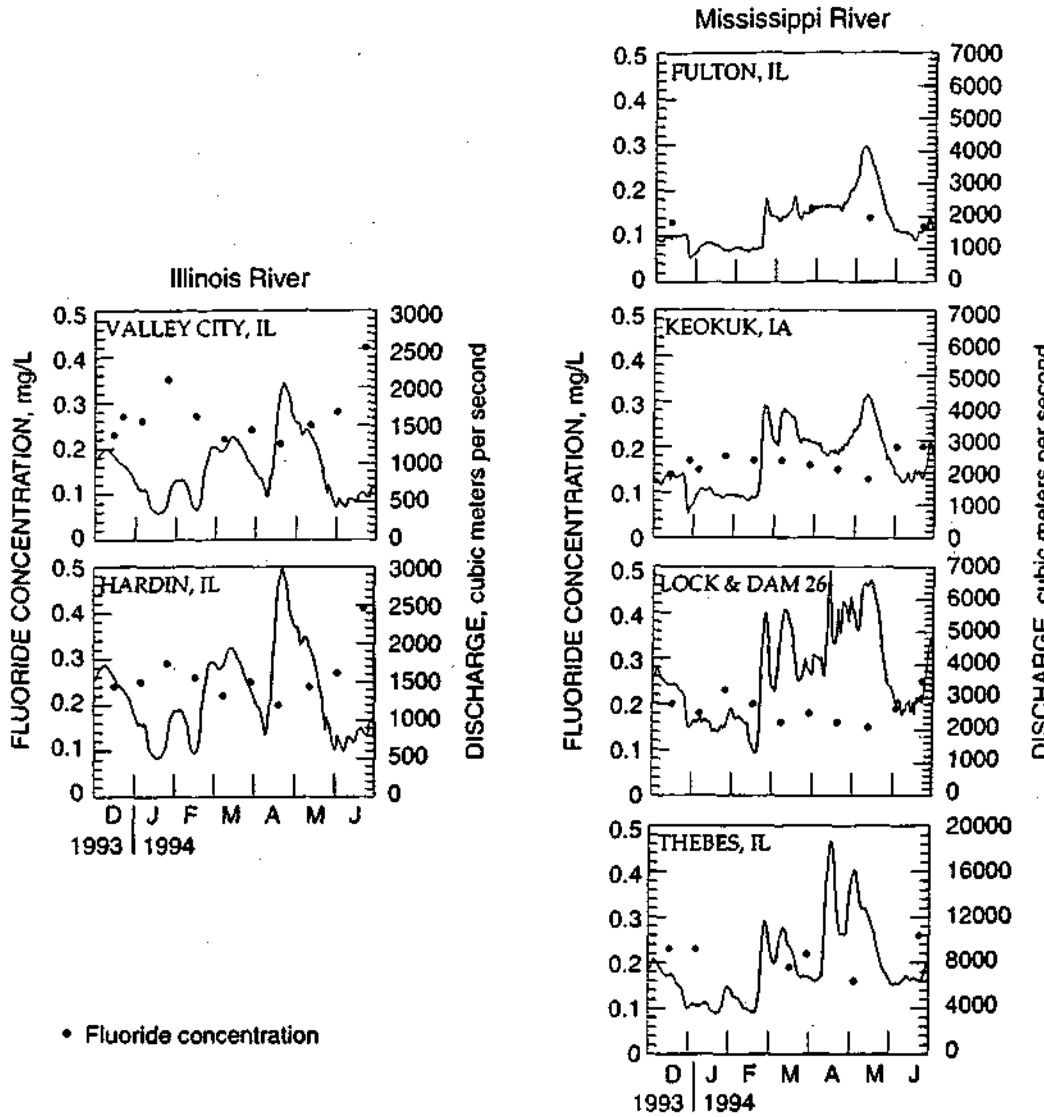

Figure 7. Fluoride Concentrations at each Sampling Station during the Study Period

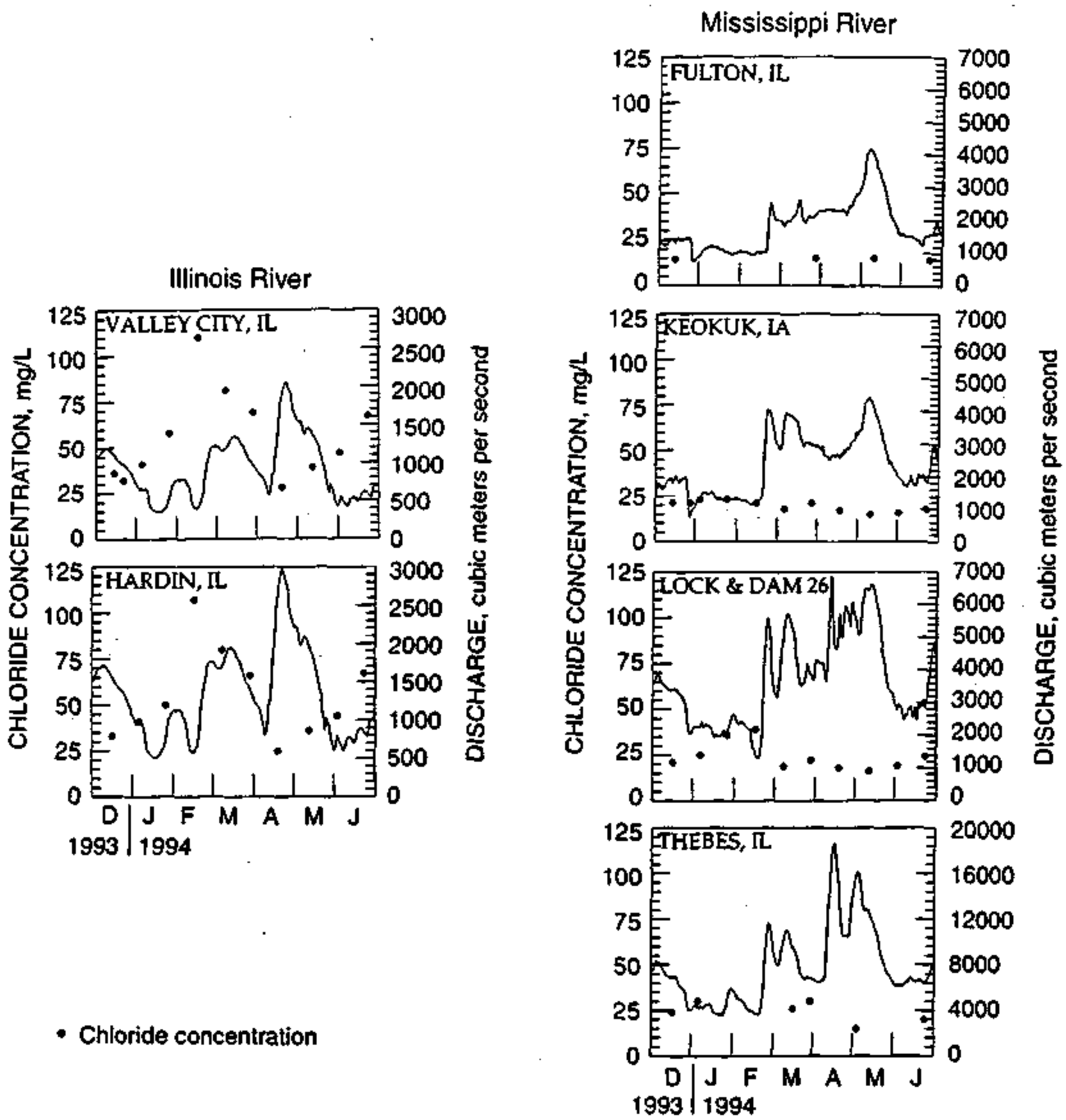

Figure 8. Chloride Concentrations at each Sampling Station during the Study Period

Sulfate. Figure 9 shows the individual data for sulfate. The mean sulfate concentration was significantly elevated at Fulton and slightly elevated at Keokuk. Sulfur is widely distributed in reduced form in both igneous and sedimentary rocks as metallic sulfides. When sulfide minerals undergo weathering in contact with aerated water, the sulfur is oxidized to yield sulfate ions that go into solution in water (Hem, 1985). In addition, biological and biochemical processes can also add dissolved sulfur to river water. At the same time, modern industrial civilization is making a substantial contribution to the cycling rate, through activities such as the combustion of fuels and the smelting of ores. These sources contribute sulfur directly to runoff, or they circulate sulfur to the atmosphere, which then returns it to the earth's surface in rainfall or dry fallout. The Illinois River, affected by larger cities on its upper reaches, showed higher sulfate concentrations and more fluctuations than those on the Mississippi River. There is no apparent trend in these data, and the fluctuations seem to be reversely correlated to discharges.

Total Alkalinity. Alkalinity is higher on the Illinois River than the Mississippi River, as shown in figure 10. Alkalinity is the opposite of acidity, which for water is "the quantitative capacity of aqueous media to react with hydroxyl ions" (ASTM, 1964). A water that is appreciably acidic will be highly aggressive; i.e., it will have a high reaction affinity toward dissolution of many of the solids that it is likely to encounter in a natural system.

Sources of acidity include sulfide minerals; metal ions, such as ferrous and ferric iron; and many other sediments at or near the surface containing enough reduced minerals to reduce the pH of natural runoff. Gases from combustion products vent to the atmosphere and contribute to the lowering of pH in rainfall in many industrialized regions.

The alkalinity of natural waters can be assigned entirely to dissolved bicarbonate and carbonate, except in the case of waters having high pH (>9.5) or others having unusual chemical composition (Hem, 1985). The CO_2 gas fraction of the atmosphere, or the atmospheric gases present in the soil or in the unsaturated zone lying between the surface of the land and water table, is the principal source of carbon dioxide that produces alkalinity in surface or groundwater. Human activities, such as fossil fuel consumption, can substantially affect the carbon cycle. Local sources include biologically mediated sulfate reduction and metamorphism of carbonate rocks. Figure 10 shows that total alkalinity concentrations were higher and fluctuated more on the Illinois River than the Mississippi River. However, once the Illinois River entered the Mississippi River, total alkalinity concentrations at L&D 26 also became higher. With the collected data, one can observe similar temporal patterns at Valley City, Hardin, L&D 26, and, to some extent, Thebes. Also, the DFMs were consistently positive at all stations, although they were not elevated.

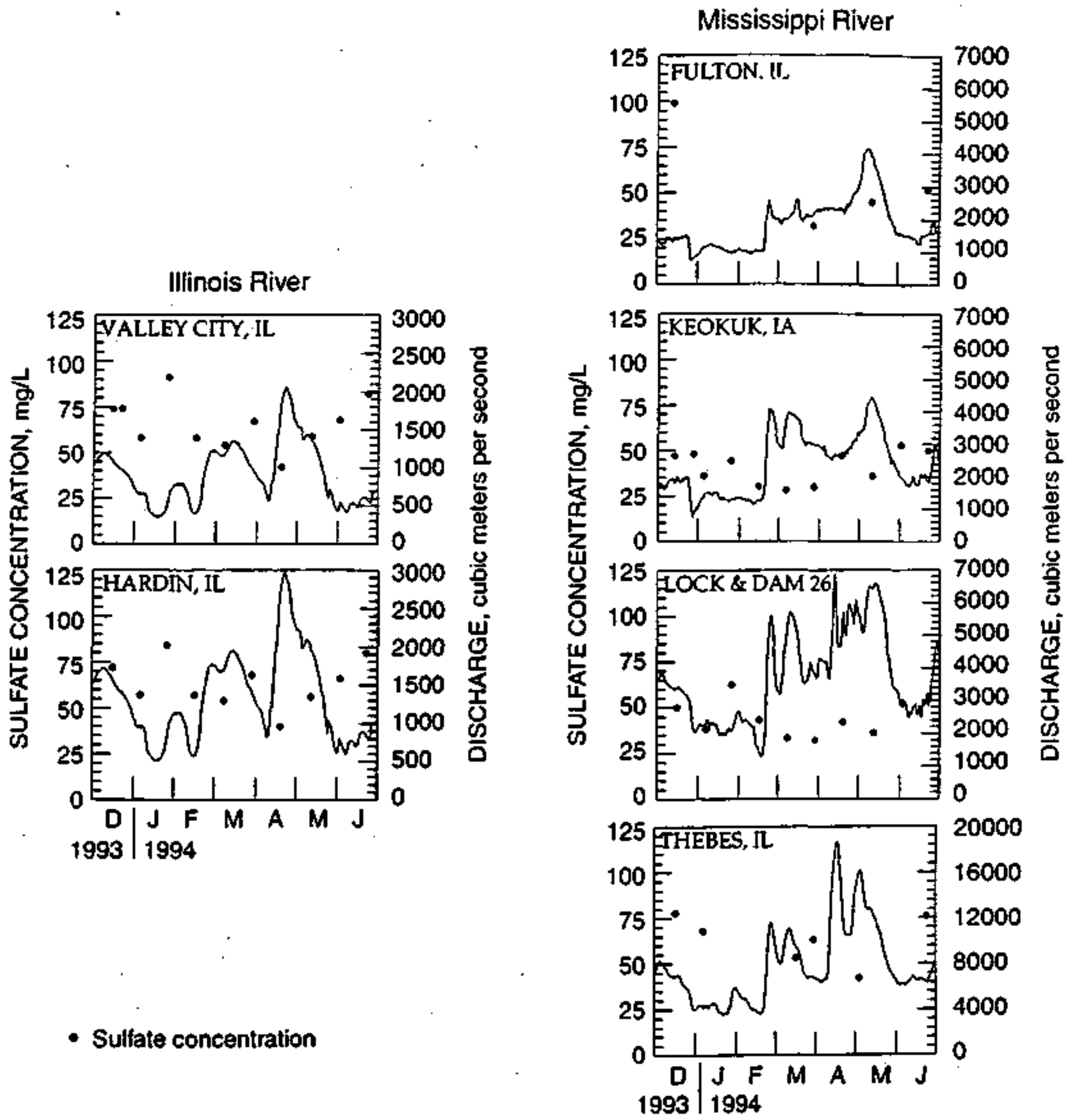

Figure 9. Sulfate Concentrations at each Sampling Station during the Study Period

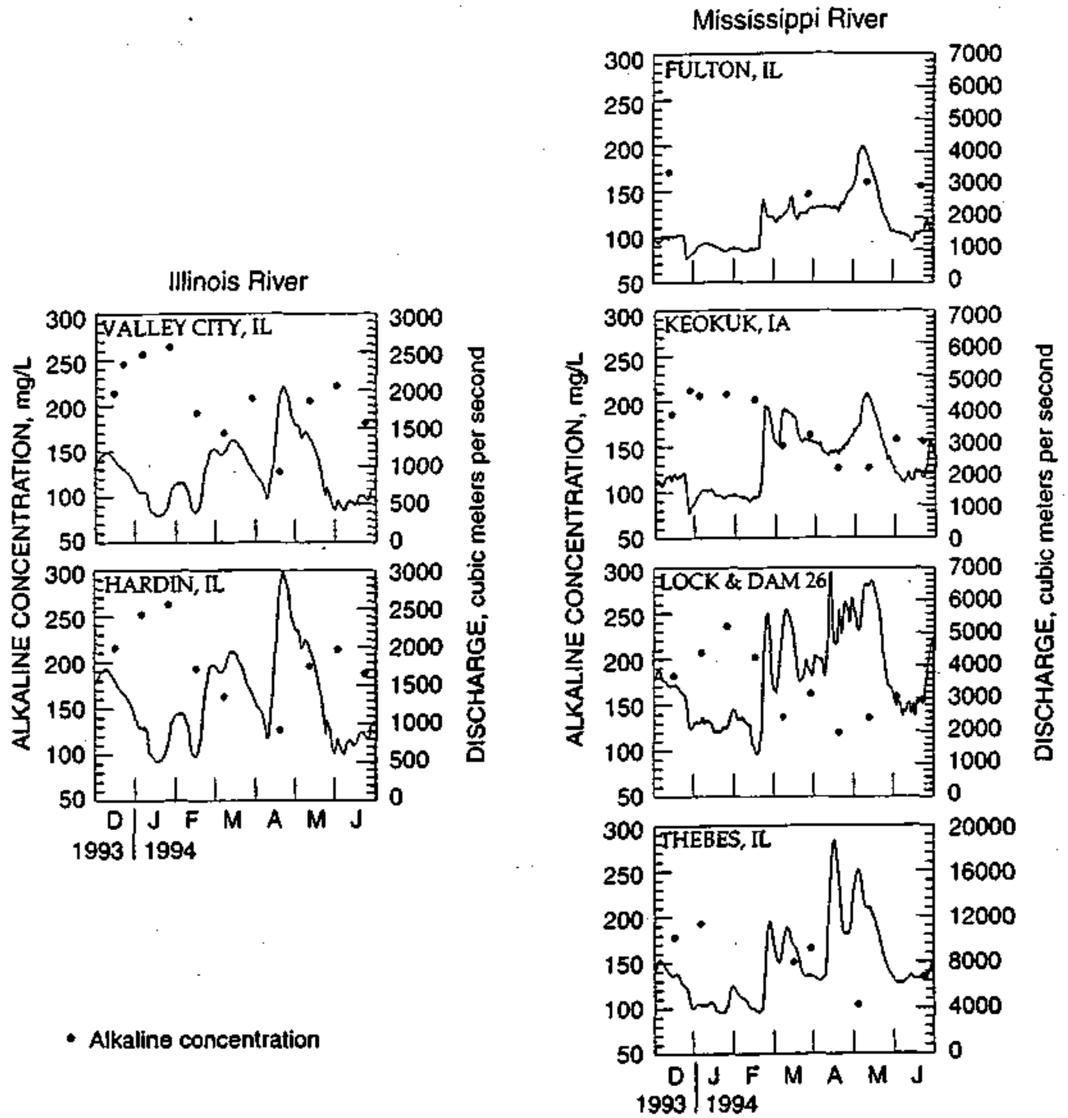

Figure 10. Total Alkalinity at each Sampling Station during the Study Period

Total Kjeldahl Nitrogen. The TKN data were consistently near or below the long-term means at all stations, and DFMs at all stations were negative. The TKN data are shown in figure 11. The new minimum at Hardin occurred on 6/22/94, at Keokuk on 12/28/93, and at L&D 26 on 6/22/94. The concentrations were similar at all stations.

PEST1 Parameters

Comparison to Historical Data

During the study period, only alachlor, atrazine, cyanazine, and metolachlor of PEST 1 had detectable values; almost all CORE2 parameters were below detection limits. However, historical data indicated that values exist at all stations for PCP (PentaChloroPhenol) and dieldrin, at Valley City and Hardin for chlordane trans isomer, and at Hardin for PCBs. Tables 27a-f list statistics for alachlor, atrazine, cyanazine, and metolachlor. It is noted that values with set detection limits were used in calculating the statistics for the study period. Because the actual data may have values lower than the detection limits, the lower limits will not be discussed for PEST1 parameters. By comparing current data with available historic data, one can observe the following:

- Hardin: a new maximum of metolachlor occurred on 4/19/94. The discharge that day was also the highest during the study period.
- Fulton: a new maximum of atrazine occurred on 6/21/94.
- L&D 26: comparisons cannot be made because of limited historical data. Given the available data, concentrations of alachlor, atrazine, cyanazine, and metolachlor all had new maximum values.

Because of limited historical data for these parameters, it was not possible to demonstrate whether they had elevated or reduced DFMs after the flood. However, concentrations of pesticides depend highly on their application and timing of rainfall, and they vary significantly from season to season. Moyer and Cross (1990) found mean atrazine concentrations to be significantly higher in spring and summer than fall and winter (1985-1988 data). The mean values for alachlor, cyanazine, metolachlor, and metribuzin, however, were not significantly different for spring, fall, and winter. Metolachlor was detected in fall during low flows, indicating that some heavily used herbicides can persist at low concentrations for long periods of time in surface water and ground-water reservoirs.

Comparison of Individual Data

Figure 12 contains the plots of alachlor levels at all stations. Detectable values were mostly recorded later in the study period, which corresponds with the application of alachlor in

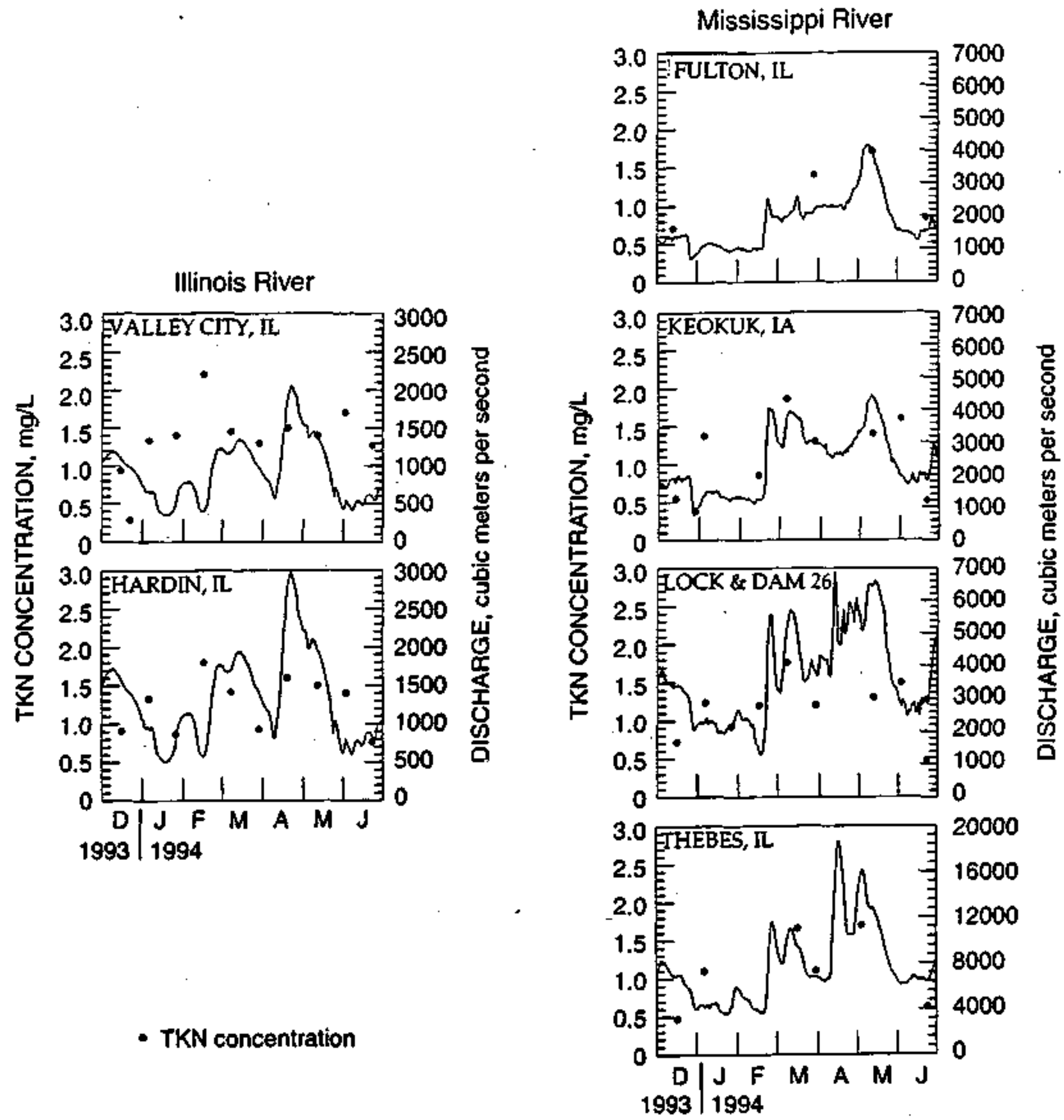

Figure 11. TKN Concentrations at each Sampling Station during the Study Period

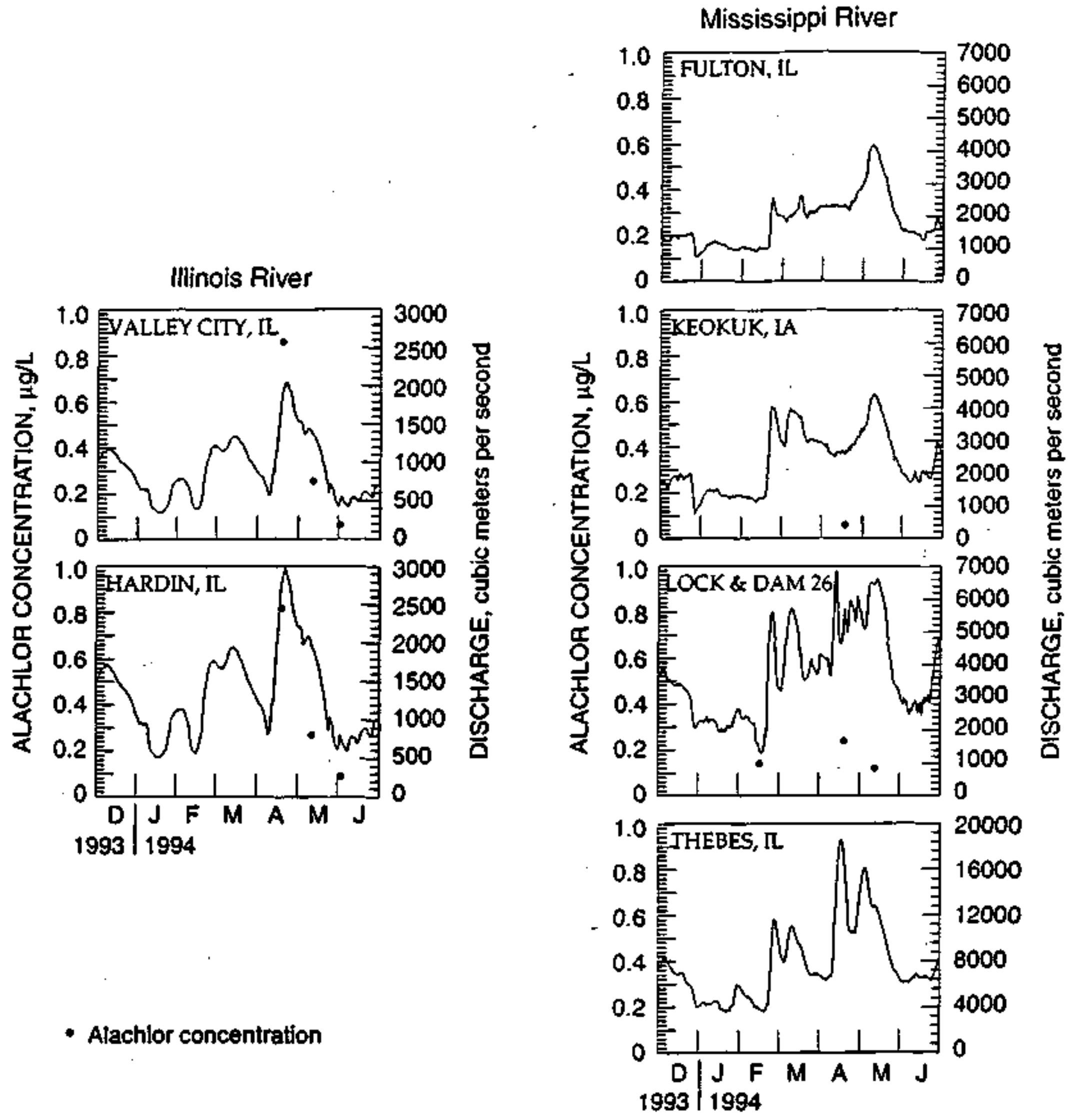

Figure 12. Alachlor Concentrations at each Sampling Station during the Study Period

the field. Similar patterns can be observed in figures 13, 14, and 15 for atrazine, cyanazine, and metolachlor, respectively. The concentrations were very high in April on the Illinois River even though the stages or discharges were high; the concentrations then decreased towards June when discharges were low, and then increased again.

Table 27a. Statistics for Selected PEST1 Parameters at Valley City

	Alachlor	*Atrazine*	*Cyanazine*	*Metolachlor*
Study period				
No. of samples	10	10	10	10
maximum	0.860	5.400	5.200	3.200
minimum	0.020	0.050	0.050	0.100
mean	0.131	1.310	1.167	0.634
DFM	-	-	-	-
Long-term data	*Not Available*			

Table 27b. Statistics for Selected PEST1 Parameters at Hardin

	Alachlor	*Atrazine*	*Cyanazine*	*Metolachlor*
Study period				
No. of samples	10	10	10	10
maximum	0.820	5.800	6.600	2.900
minimum	0.020	0.050	0.050	0.100
mean	0.132	1.600	1.527	0.608
DFM	-0.263	-0.275	-0.044	0.009
Long-term data				
No. of samples	7	7	7	7
maximum	1.000	8.800	9.000	2.700
minimum	0.020	0.050	0.050	0.100
mean	0.226	2.677	1.674	.600
stand. dev.	.358	3.923	3.325	.939

Table 27c Statistics for Selected PEST1 Parameters at Fulton

	Alachlor	*Atrazine*	*Cyanazine*	*Metolachlor*
Study period				
No. of samples	3	3	3	3
maximum	0.020	0.950	0.050	0.100
minimum	0.020	0.050	0.050	0.100
mean	0.020	0.350	0.050	0.100
DFM	-	-	-	-
Long-term data				
No. of samples	1	1	1	1
maximum	0.360	0.890	0.400	0.250
minimum	0.360	0.890	0.400	0.250
mean	0.360	0,890	0.400	0.250
stand. dev.	-	-	-	-

Table 27d. Statistics for Selected PEST1 Parameters at Keokuk

	Alachlor	*Atrazine*	*Cyanazine*	*Metolachlor*
Study period				
No. of samples	10	10	10	10
maximum	0.100	2.000	0.170	0.100
minimum	0.020	0.050	0.050	0.100
mean	0.032	0.364	0.068	0.100
DFM				
Long-term data	*Not Available*			

Table 27e. Statistics for Selected PEST1 Parameters at L&D 26

	Alachlor	*Atrazine*	*Cyanazine*	*Metolachlor*
Study period				
No. of samples	10	10	10	10
maximum	0.240	2.400	1.900	0.750
minimum	0.020	0.050	0.050	0.100
mean	0.064	0.544	0.467	0.204
DFM	-	-	-	-
Long-term data				
No. of samples	1	1		1 1
maximum	0.092	0.620	0.050	0.170
minimum	0.092	0.620	0.050	0.170
mean	0.092	0.620	0.050	0.170
stand. dev.	-	-	-	-

Table 27f. Statistics for Selected PEST1 Parameters at Thebes

	Alachlor	*Atrazine*	*Cyanazine*	*Metolachlor*
Study period				
No. of samples	2	2	2	2
maximum	0.020	0.550	0.110	0.100
minimum	0.020	0.050	0.050	0.100
mean	0.020	0.300	0.080	0.100
DFM	-	-	-	-
Long-term data	*Not Available*			

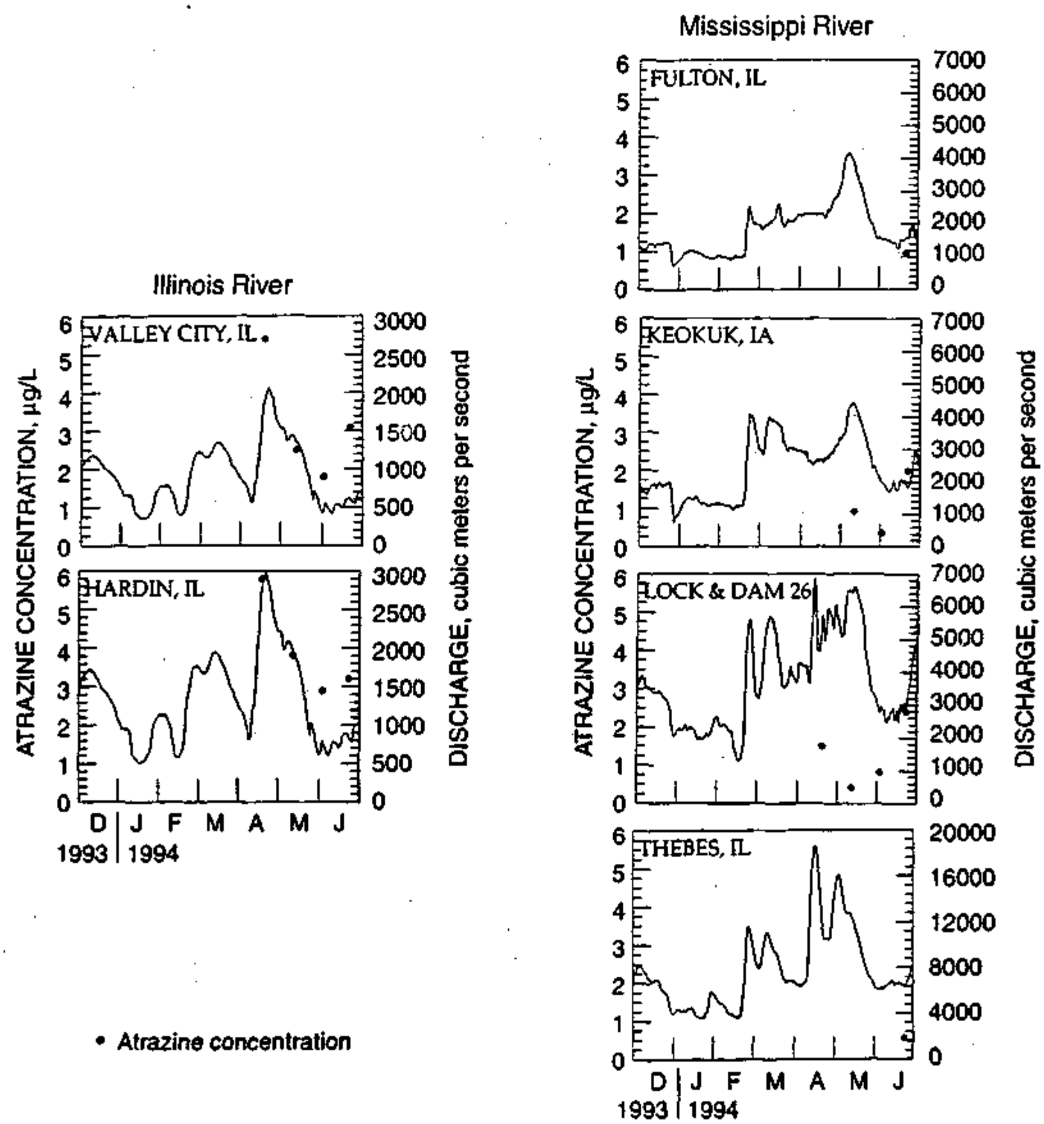

Figure 13. Atrazine Concentrations at each Sampling Station during the Study Period

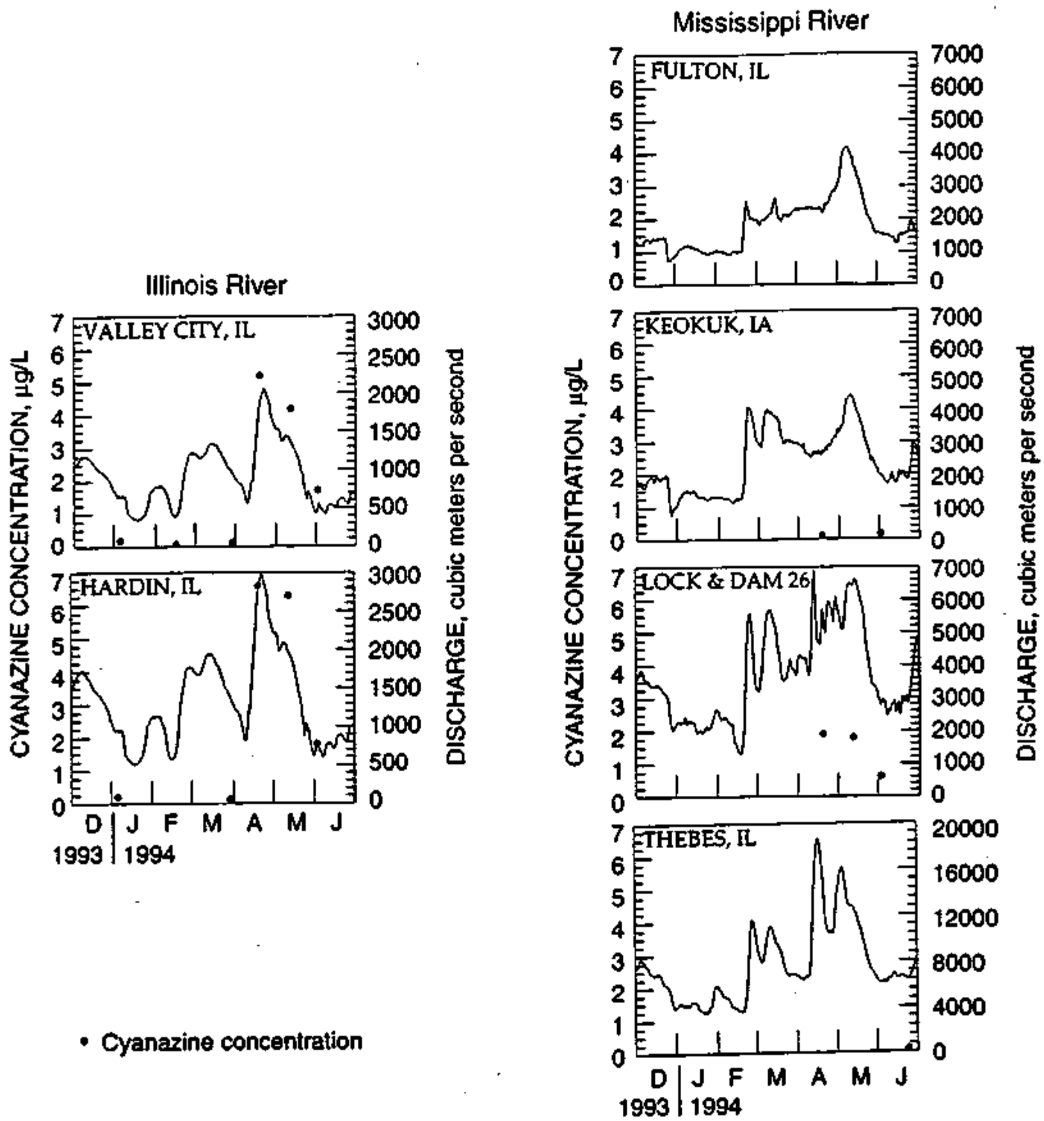

Figure 14. Cyanazine Concentrations at each Sampling Station during the Study Period

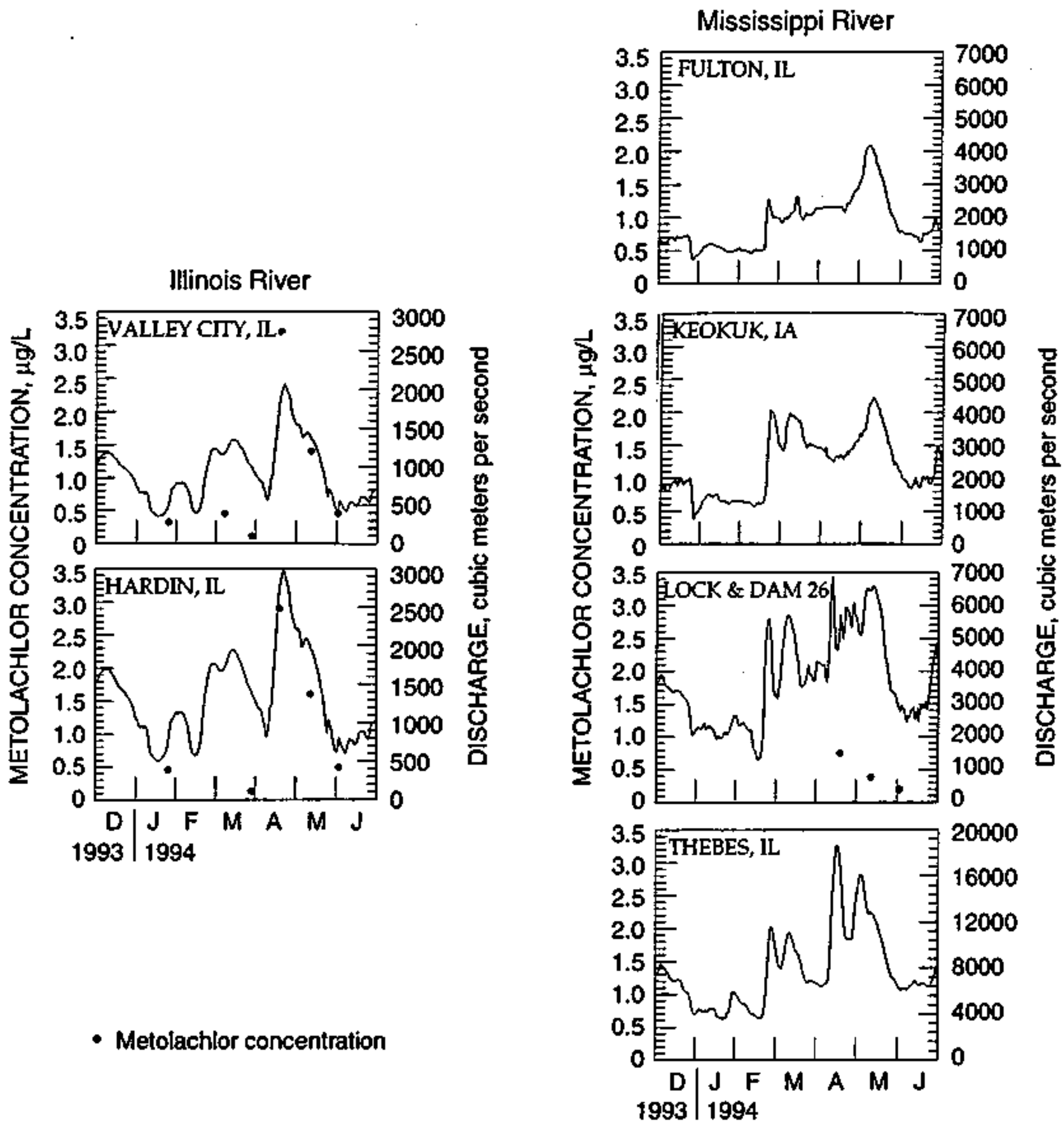

Figure 15. Metolachlor Concentrations at each Sampling Station during the Study Period

CORE3 Parameters

Since data available for CORE3 parameters were collected on December 13, 1993, and most detectable data were at Valley City, the historical data for Valley City are presented in table 28.

Table 28. Historical Data at Valley City for Selected CORE3 Parameters

	PCBs	*Aldrin*	*Dieldrin*	*Tot. DDT*	*o.pDDE*	*p.p'DDE*	*o.pDDD*	*p.p'DDD*	*o.pDDT*	*p.p'DDT*
No. o f samples	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
maximum	**10.0**	**1.0**	**3.7**	**10.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
minimum	**10.0**	**1.0**	**1.0**	**10.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
mean	**10.0**	**1.0**	**2.1**	**10.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
stand. dev.	**0.0**	**0.0**	**1.181**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Because the historical data did not contain many detectable values, all the measurable values in December 1993 were new maximums at this site. These include PCBs, aldrin, dieldrin, p,p'DDE , p,p' DDD, and endrin. The appearance of these organic compounds merit further investigation. Hardin and Valley City were subjected to the backwater effects from the high stages on the Mississippi River during the 1993 flood. Hence, sediment brought from the upper Illinois River was likely to be deposited in this reach instead of traveling to the Mississippi River as it would under normal conditions.

CORE4 Parameters

Comparison to Historical Data

Reasonable historical data exist for nutrients, arsenic, and metals in sediment. It should be noted that cadmium and mercury were all under detection limits during the study period, but were detectable in the long-term data at the sampling locations. Tables 29a-f list the statistics for the remaining parameters. From these tables, one can observe the following:

- Valley City: both TKN and total phosphorus had new maximum values, which occurred on 12/15/93. Mean concentrations of TKN were significantly elevated, while total phosphorus and COD were slightly elevated.
- Hardin: no historical data available.
- Fulton: a new maximum TKN value occurred on 3/28/94, and a new maximum COD value occurred on 12/31/93. TKN had a new minimum value on 6/21/94. During the study period, concentrations of TKN and COD were elevated.

Table 29a. Statistics for Selected CORE4 Parameters at Valley City

	T. Volatile percent	*TKN* mg/kg	*T. Phosph.* mg/kg	*COD* mg/kg	*Arsenic* mg/kg	*Chromium* mg/kg
Study period						
No. o f samples	3	3	3	1	3	3
maximum	5.300	3333.	838.0	44800.	4.600	17.00
minimum	4.000	1428.	620.0	44800.	3.600	12.00
mean	4.700	2383.7	698.7	44800.	3.967	15.33
DFM	0.559	3.608	1.135	1.011	-0.386	-0.181
Long-term data						
No. of samples	5	5	5	5	5	5
maximum	6.200	1660.	773.0	59000.	8.200	22.00
minimum	2.900	691.0	326.0	13500.	3.000	10.00
mean	3.900	965.4	512.4	25610.	4.740	16.20
stand, dev.	1.430	393.1	164.1	18983.7	2.004	4.817

	Copper ***mg/kg***	***Iron*** ***mg/kg***	***Lead*** ***mg/kg***	***Manganese*** ***mg/kg***	***Zinc*** ***mg/kg***
Study period					
No. of samples	3	3	3	3	3
maximum	17.00	18000.	28.00	765.0	84.00
minimum	11.00	14000.	15.00	526.0	46.00
mean	14.33	16333.3	20.00	636.0	69.00
DFM	-0.205	-0.146	-0.358	0.372	0.054
Long-term data					
No. of samples	5	5	5	5	5
maximum	32.00	26000.	43.00	990.0	96.00
minimum	10.00	13000.	9.000	340.0	48.00
mean	16.20	17080.	24.60	540.0	68.00
stand. dev.	9.121	5111.9	12.84	258.2	18.51

Table 29b. Statistics for Selected CORE4 Parameters at Hardin

	T. Volatile percent	*TKN mg/kg*	*T. Phosph mg/kg*	*COD mg/kg*	*Arsenic mg/kg*	*Chromium mg/kg*
Study period						
No. o f samples	3	3	3	1	3	3
maximum	5.800	1379.	722.0	19900.	6.800	21.00
minimum	3.800	5.600	544.0	19900.	4.000	17.00
mean	4.667	863.2	621.0	19900.0	5.333	18.33
DFM						
Long-term data	*Not Available*					

	Copper mg/kg	*Iron mg/kg*	*Lead mg/kg*	*Manganese mg/kg*	*Zinc mg/kg*
Study period					
No. of samples	3	3	3	3	3
maximum	21.00	19000.	25.00	833.0	99.00
minimum	15.00	19000.	16.00	617.0	58.00
mean	17.67	19000.	19.00	758.7	73.67
DFM					
Long-term data	*Not Available*				

Table 29c Statistics for Selected CORE4 Parameters at Fulton

	T. Volatile percent	*TKN mg/kg*	*T. Phosph mg/kg*	*COD mg/kg*	*Arsenic mg/kg*	*Chromium mg/kg*
Study period						
No. of samples	3	3	3	1	3	3
maximum	4.500	3286.	585.0	39600.	4.100	15.00
minimum	3.200	105.0	401.0	39600.	2.500	9.000
mean	3.667	1980.3	479.3	39600.	3.167	11.33
DFM	0.584	2.371	0.322	2.021	0.532	-0.612
Long-term data						
No. of samples	10	10	10	10	8	10
maximum	4.900	1780.	627.0	28700.	4.000	32.00
minimum	1.000	450.0	170.0	14.00	1.200	4.000
mean	2.930	1064.6	439.9	17236.7	2.750	16.43
stand. dev.	1.261	386.2	122.5	11066.2	.784	8.33

	Copper mg/kg	*Iron mg/kg*	*Lead mg/kg*	*Manganese mg/kg*	*Zinc mg/kg*
Study period					
No. of samples	3	3	2	3	3
maximum	11.00	15000.	12.00	822.0	55.00
minimum	6.000	11000.	12.00	555.0	35.00
mean	8.333	12666.7	12.00	678.0	43.67
DFM	-0.305	0.294	-0.265	0.101	-0.815
Long-term data					
No. of samples	10	10	10	8	10
maximum	15.00	15400.	27.00	1300.	140.0
minimum	2.000	5400.	5.000	250.00	17.00
mean	9.460	11815.3	13.64	645.9	70.52
stand. dev.	3.692	2894.5	6.190	317.8	32.93

Table 29d. Statistics for Selected CORE4 Parameters at Keokuk

	T. Volatile percent	*TKN mg/kg*	*T. Phosph mg/kg*	*COD mg/kg*	*Arsenic mg/kg*	*Chromium mg/kg*
Study period						
No. o f samples	3	3	3	1	3	3
maximum	6.500	1594.	949.0	13650.	4.000	16.00
minimum	1.600	145.0	208.0	13650.	2.500	3.000
mean	4.200	682.0	649.3	13650.	3.333	11.33
DFM	-0.415	-1.100	0.573	-0.789	-0.087	-1.412
Long-term data						
No. o f samples	7	7	7	7	7	7
maximum	13.300	3850.	762.0	120000.	4.700	21.80
minimum	2.300	944.0	340.0	14600.	2.000	11.00
mean	5.729	1779.1	576.0	41614.3	3.414	16.26
stand. dev.	3.686	997.8	128.0	35429.	.930	3.492

	Copper mg/kg	*Iron mg/kg*	*Lead mg/kg*	*Manganese mg/kg*	*Zinc mg/kg*
Study period					
No. of samples	3	3	2	3	3
maximum	14.00	17000.	17.00	793.0	65.00
minimum	1.000	4500.	13.00	255.0	9.000
mean	9.000	12166.7	15.00	601.3	44.33
DFM	-0.595	-0.706	-0.825	-0.694	-1.118
Long-term data					
No. of samples	7	7	7	7	7
maximum	32.00	19844.	29.00	1000.	90.00
minimum	7.000	9000.	9.000	460.00	42.00
mean	14.23	15034.9	21.29	733.9	66.30
stand. dev.	8.788	4062.4	7.631	191.1	19.65

Table 29c Statistics for Selected CORE4 Parameters at L&D 26

	T. Volatile percent	*TKN mg/kg*	*T. Phosph mg/kg*	*COD mg/kg*	*Arsenic mg/kg*	*Chromium mg/kg*
Study period						
No. of samples	3	1	3	1	3	3
maximum	3.700	174.0	433.0	2800.	5.300	13.00
minimum	1.000	174.0	109.0	2800.	1.400	4.000
mean	2.733	174.0	324.0	2800.	3.500	9.000
DFM	-1.056	-5.122	-1.102	-2.595	-0.669	-1.402
Long-term data						
No. of samples	9	9	9	9	9	9
maximum	6.900	1140.	892.0	48000.	5.200	21.00
minimum	2.800	716.0	341.0	16400.	2.700	11.00
mean	4.512	897.8	534.2	26633.3	4.067	13.44
stand. dev.	1.685	141.3	190.8	9182.9	.847	3.167

	Copper mg/kg	*Iron mg/kg*	*Lead mg/kg*	*Manganese mg/kg*	*Zinc mg/kg*
Study period					
No. o f samples	3	3	1	3	3
maximum	10.00	14000.	16.00	481.0	45.00
minimum	1.000	5000.	16.00	95.00	10.00
mean	6.000	10000.	16.00	336.3	28.67
DFM	-2.207	-1.567	0.278	-0.755	-2.736
Long-term data					
No. of samples	9	9	9	9	9
maximum	17.00	27000.	23.00	1800.	71.00
minimum	7.90	12000.	4.200	440.0	41.20
mean	13.42	16826.3	14.48	665.5	56.91
stand. dev.	3.362	4356.3	5.469	436.0	10.32

Table 29f. Statistics for Selected CORE4 Parameters at Thebes

	T. Volatile percent	*TKN mg/kg*	*T. Phosph mg/kg*	*COD mg/kg*	*Arsenic mg/kg*	*Chromium mg/kg*
Study period						
No. o f samples	3	3	3	1	3	3
maximum	8.700	1032.	683.0	5750.	5.000	16.00
minimum	1.000	6.200	265.0	5750.	2.900	3.000
mean	4.233	359.4	464.0	5750.	3.600	10.67
DFM						
Long-term data	*Not Available*					

	Copper mg/kg	*Iron mg/kg*	*Lead mg/kg*	*Manganese mg/kg*	*Zinc mg/kg*
Study period					
No. of samples	3	3	3	3	3
maximum	18.00	19000.	21.00	1000.	69.00
minimum	1.000	4200.	10.00	78.00	14.00
mean	10.00	12400.	15.33	543.7	44.00
DFM					
Long-term data	*Not Available*				

- Keokuk: a new maximum for total phosphorus occurred on 3/28/94. Almost all parameters, except for arsenic and lead, had new minimum values on 12/14/93. The mean TKN concentration was slightly reduced. It should also be noted that the DFMs of all metals were reduced during the study period, while the degree of reduction for chromium and zinc became larger than one standard deviation.
- L&D 26: reduction in CORE4 parameters was obvious at this station. All parameters except for lead had their new minimum values on 12/16/93. Using the DFM definition, TKN was significantly reduced; COD, copper, and zinc were reduced; and total volatile residues, total phosphorus, chromium, and iron were slightly reduced.
- Thebes: no historical data available.

The consistent reduction in sediment quality parameters at Keokuk and, more obviously, at L&D 26 may reflect the physical processes that occurred during the 1993 flood: settled sediment was agitated, transported, and redistributed in the reach of the Mississippi that was severely flooded. It is reasonable to postulate that, at locations where deposition occurred, the concentrations would be high initially and then decrease toward historical means gradually over the study period. Conversely, at locations where erosion occurred, the concentration would be lower initially and then increase toward historical means during the study period. The representativeness of using historical means for actual means is a point worth further consideration.

Plots were developed for all CORE4 parameters. Plotting data over a long time span helps in examining trends. Since discharge indicates a flow's carrying power (hence possible sediment deposition or entrenchment), discharge data were also plotted. These figures are presented in Appendix C. From these plots, one can observe a decreasing trend at two upper stations (Valley City on the Illinois River and Fulton on the Mississippi River), while increasing trends exist at L&D 26 and Thebes on the Mississippi.

EVENTS DURING THE 1995 FLOOD

During 1995, the State of Illinois experienced another major flood whose peak stages on the middle reaches of the Illinois River were comparable to or, at some locations, exceeded stages during the 1993 flood. No levee breach or severe inundation was reported, however. ISWS and EEPA staff took the opportunity to collect CORE1 samples during the peak stage of the 1995 flood. Since the flood was limited mostly to the Illinois River, data were collected at Hardin and L&D 26 in May 1995. Tables 30a and b present the collected data.

Table 30a. CORE1 Parameters at Hardin, May 1995

Date	*Cyanide mg/L*	*Arsenic fjg/L*	*Phenol fjg/L*	*Fluoride mg/L*	*Mercury mg/L*	*Chloride mg/L*	*Sulfate mg/L*	*T.Acid mg/L*	*Alka. mg/L*	*TKN mg/L*
05/22	.010K	1K	10K	.21	.05K	18	28		118	.990
05/23	.010K	1K	10K	.21	.05K	19	31		122	.870
05/24	.010K	1	10K	.21	.05K	20	31		123	.930

Table 30b. CORE1 Parameters at L&D 26, May 1995

Date	*Cyanide mg/L*	*Arsenic µg/L*	*Phenol µg/L*	*Fluoride mg/L*	*Mercury mg/L*	*Chloride mg/L*	*Sulfate mg/L*	*T. Acid mg/L*	*Alka. mg/L*	*TKN mg/L*
05/22	.010K	1K	10K	.24	.05K	19	36	-	144	.870
05/23	.010K	1K	10K	.21	.05K	16	39	-	150	.870
05/24	.010K	1K	10K	.21	.05K	16	42	-	159	.770

It was later verified that sampling dates were about a week or so before the peak stages. It will be interesting to compare this dataset with representative values from the long-term and study periods. Table 31 presents the results of a comparison with statistics from tables 26a, b, and e (CORE1 for the study period).

Table 31a. Comparisons of 1995 Data to Historical and 1993 Data, Hardin

Parameter mg/L	*1995 mean*	*Historical mean*	*Historical min.*	*1993 mean*	*Historical min.*
Fluoride	**.21**	**-**	**-**	**.263**	**.200**
Chloride	**19**	**62.83**	**26.00**	**55.02**	**25.2**
Sulfate	**30**	**-**	**-**	**63.4**	**40.00**
Tot.Alk.	**121**	**189.4**	**116.0**	**201.3**	**127.0**
TKN	**.93**	**1.54**	**1.10**	**1.25**	**0.76**

Table 31b. Comparisons of 1995 Data to Historical and 1993 Data, L&D 26

Parameter mg/L	*1995 mean*	*Historical mean*	*Historical min.*	*1993 mean*	*Historical min.*
Fluoride	**.22**	**.222**		**.190**	
Chloride	**17**	**23.19**	**8.1**	**23.89**	**16.00**
Sulfate	**39**	**44.42**	**15.00**	**44.40**	**32.00**
Tot. Alk.	**151**	**156.5**	**100.0**	**169.7**	**120.0**
TKN	**.84**	**1.491**	**0.50**	**1.253**	**0.48**

It can be seen that the data from the 1995 flood are biased toward the lower limits of the statistics. Notable points for 1995 data are listed below.

- Chloride concentrations were even lower than the post-flood record at Hardin and set a new record low.
- Sulfate concentrations were also very low. Like chloride, sulfate had a new minimum at Hardin.
- Total alkalinity was low at Hardin but approximated a long-term mean at L&D 26.
- TKN was low at both stations.

Dilution of chemical concentrations during floods is expected. If there were no new sources during the flood, then the concentrations would become lower than normal values. This was shown in the 1995 flood, which is also a major flood but without significant inundation of agricultural lands and urban areas except for tributary input. Still, data collected during the 1993 flood were not much different from non-flood years (USGS, 1993), as illustrated in table 11. This is another unique feature of the 1993 flood.

SUMMARY

The 1993 flood was an unusual hydrometeorologic event in which intense rainfall caused prolonged flooding and inundation of vast areas of the Upper Mississippi River (UMR) basin. This unprecedented climatic and hydrologic phenomenon resulted in several deaths and devastating property losses. Runoff also carried unusually large amounts of pollutants from point and nonpoint sources to the rivers. In order to determine the flood's impacts on the Mississippi and Illinois Rivers, the Illinois State Water Survey (ISWS) and the Illinois Environmental Protection Agency (IEPA) conducted this joint investigation, sampling selected water and sediment quality parameters from six stations over a seven-month period. This report summarizes the design of the project, data collection procedures, results, and analyses.

Parameters collected include: inorganics and organics in water (CORE1 and PEST1 groups in IEPA's ambient water quality program), organics in sediment (CORE3), and nutrients and metals in sediment (CORE4). The collection, preservation, and transportation of the water and sediment samples followed the procedures given in the IEPA *Quality Assurance and Field Methods Manual.* Lab analyses of CORE1, PEST1, and CORE4 parameters from all trips and CORE3 parameters from one trip were completed when this report was prepared. Results were retrieved from the STORET database and presented in the report.

The collected data represent the period from December 1993 to June 1994, immediately following the flood. They were analyzed for any violation of established standards, and new records were compared to historical data to determine elevated or reduced levels of any parameters.

The results showed that concentrations of many water quality parameters were below detection limits during the study period. For those parameters that showed detectable values, concentrations were mostly below established water quality standards. This may explain the impression common among other studies related to the 1993 flood that either the flood's impacts were insignificant or data collection started late.

Water quality parameters that showed detectable values were:

- chloride, sulfate, alkalinity, and TKN (CORE1);
- alachlor, atrazine, cyanazine, and metolachlor (PEST1).

Sediment quality parameters that showed detectable values were:

- p,p'DDE at Hardin;
- p,p'DDE, PCBs, aldrin, dieldrin, and p,p'DDD at Valley City; and
- almost all CORE4 parameters at each station.

Currently there are no established standards for sediment quality. By using the mean values reported previously by IEPA (Kelly and Hite, 1984), it is noted that:

- the measured PCBs at Valley City were much higher than the background means, and
- chromium appeared to exceed the background mean at all stations.

Another set of data are temperature, DO, pH, and conductivity collected from the field. This study found that:

- higher pH values were observed in winter on two Illinois River stations, and
- lower DO values were measured in summer at all stations. The low DO values on the Illinois River were lower than IEPA specifications for secondary contact.

Parameters with detectable values were compared to historical data whenever available. In addition to identifying whether new maximum or minimum values of these parameters occurred in the study period, a DFM (deviation from mean) was used to determine whether the parameter mean over the study period was slightly elevated or reduced, elevated or reduced, or significantly elevated or reduced (see the section titled *Analyses).* Having historical data available was invaluable for the analysis.

The following observations apply to the study period:

CORE1 Parameters

- <u>Sulfate</u>: there was a new maximum at Fulton on 12/13/93; while overall values were slightly elevated at Fulton and Keokuk.
- <u>Total Alkalinity</u>: new maximums were observed at Valley City, Hardin, and L&D 26 on 1/25/94.
- <u>TKN</u>: new minimums were observed at Hardin (6/22/94), Keokuk (12/18/93), and L&D 26 (6/22/94).

PEST1 Parameters

- <u>Atrazine</u>: a new maximum occurred at Fulton on 6/21/94.
- <u>Metolachlor</u>: a new maximum occurred at Hardin on 4/19/94.

Note: Comparisons cannot be made at L&D 26 due to limited historical data. Given the available data, concentrations of alachlor, atrazine, cyanazine, and metolachlor all had new maximum values.

CORE4 Parameters

- <u>TKN</u>: new maximums occurred at Valley City (12/15/93) and at Fulton (3/28/94). However, new minimums occurred at Fulton (6/21/94) and at Keokuk and L&D 26 on 12/14/93. The overall mean was significantly elevated at Valley City, elevated at Fulton, slightly reduced at Keokuk, and significantly reduced at L&D 26.

  Note: No historical data were available at Hardin and Thebes.
- <u>Total phosphorus</u>: new maximums were observed at Valley City (12/15/93), and at Keokuk (3/28/94); while new minimums were observed at Keokuk and L&D 26 on 12/16/93. The overall mean was slightly elevated at Valley City but slightly reduced at L&D 26.

- COD: a new maximum value occurred at Fulton (12/31/93) while a new minimum occurred at Keokuk (12/14/93). COD was slightly elevated at Valley City and elevated at Fulton.

Note: At Keokuk almost all parameters except for arsenic and lead had new minimum values on 12/14/93. It should also be noted that all metals' DFMs were reduced over the study period, while the degree of reduction for chromium and zinc was larger than 1 standard deviation. Reductions in CORE4 parameters were obvious at L&D 26. All parameters except for lead had new minimum values on 12/16/93. According to the DFM definition, TKN was significantly reduced; COD, copper, and zinc were reduced; and total volatile residues, total phosphorus, chromium, and iron were slightly reduced.

DO, pH, and Conductivity

- Conductivity: a new minimum for conductivity was measured at Valley City on 12/16/93, but new maximums were observed at Fulton (6/21/94) and Keokuk (1/24/94). A new minimum was also recorded on 12/14/93 at Keokuk. The overall mean was slightly elevated at L&D 26.
- pH: new maximums were observed at Keokuk (1/24/94), L&D 26 (1/6/94), and Thebes (12/17/93). The overall mean was slightly elevated at Valley City and Hardin.
- DO: Hardin had a new minimum on 6/22/94. On the Mississippi River, a new maximum occurred on 12/13/93 at Fulton; new minimums were also observed at Fulton on 6/2/94 and at Keokuk on 6/21/94.

The occurrence of new maximum and minimum values indicates that some modifications had occurred on the rivers. The extreme values were mostly observed at the beginning or end of the project period and demonstrated upstream to downstream patterns. It is noted that TKN had minimum values in sediment and water at Keokuk in the same period; all metals were consistently reduced at Keokuk and, more obviously, at L&D 26.

Parameters that showed new extreme values can be summarized as follows. Pesticide parameters mostly had new maximum values later in or at the end of the study period; this may have been associated with the timing of their applications. Organic compounds or nutrients in sediment had their new maximum values mostly at the beginning of the study period. Pollutants were transported either in dissolved form or attached to sediment, which was used as the transport medium. Therefore, one reasonable explanation for the new maximum and minimum values or elevated and reduced levels of sediment quality parameters is physical processes, such as sediment entrenchment, deposition, and redistribution in the channel reaches. A possible explanation for new extreme values in parameters related to natural water chemistry or basic properties may be found by examining ground-water feedback and biological activities after the 1993 flood. These processes, unlike the dominant features of the flood, are not well understood, but this report has provided background information to enhance our understanding of them.

Comparisons to historical data for those parameters with concentrations below detection limits during the study period showed another impact of the flood: the reduction of levels of various parameters. Many of these parameters have previously recorded values, including:

- CORE1 - cyanide, arsenic, phenols, and mercury; and
- CORE2 - at all stations for PCP and dieldrin, at Valley City and Hardin for chlordane trans isomer, and at Hardin for PCBs.

If the reduction in these parameters was caused by the 1993 flood, it can be considered a positive impact of the flood. However, more studies should be conducted to clearly identify the reasons for the consistency in reductions of several parameters at all stations.

An additional effort carried out by the ISWS and IEPA was the data collection run during the 1995 flood on the Illinois River. CORE1 data were collected at Hardin and L&D 26 in May, approximately one week before the flood peak. Results show that the 1995 flood data were biased toward the lower limits of the statistics for such parameters as chloride, sulfate, total alkalinity, and TKN. The 1995 flood had comparable flood stages to the 1993 flood on the middle reaches of the Illinois River, but the lower reaches were not subject to backwater effects as they had been in 1993. Moreover, the peak occurred in late May 1995, and because there was no major flood inundation of farmlands or urban areas, the loads of pollutants from increased discharge were smaller. Therefore the concentrations of chemicals during the flood were generally reduced. Still, data collected during the 1993 flood were not much different than data from non-flood years (USGS, 1993). This is another difference between the two floods.

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APPENDIX A

PEST1 Results

Table A-l. Results for PEST1 Parameters, Valley City, Illinois River

Date	*Q, cms*	*Alachlor* *μg/L*	*Atrazine* *μg/L*	*Butylate* *μg/L*	*Captan* *μg/L*	*Chloropyrifos* *μg/L*	*Cyanazine* *μg/L*	*Diazinon* *μg/L*	*Fonofos* *μg/L*	*Malathion* *μg/L*	*Parathion* *μ/L*	*Metolachlor* *μg/L*
12/15/93	1,109	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
1/5/94	659	.020K	.050K	.050K	.050K	.050K	0.18	.050K	.050K	.050K	.050K	.10K
1/25/94	538	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	0.32
2/15/94	396	.020K	.050K	.050K	.050K	.050K	0.07	.050K	.050K	.050K	.050K	.10K
3/8/94	1,177	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	0.45
3/29/94	971	.020K	.050K	.050K	.050K	.050K	0.12	.050K	.050K	.050K	.050K	0.11
4/19/94	1,893	0.86	5.4	.050K	.050K	.050K	5.2	.050K	.050K	.050K	.050K	3.2
5/12/94	1,353	0.25	2.5	.050K	.050K	.050K	4.2	.050K	.050K	.050K	.050K	1.4
6/1/94	467	0.06	1.8	.050K	.050K	.050K	1.7	.050K	.050K	.050K	.050K	0.46
6/21/94	577	.020K	3.1	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K

Date	*Q, cms*	*Metribuzin* *μg/L*	*Phorate*	*Terbufos* *μg/L*	*Trifluralin* *μg/L*
12/15/93	1,109	.050K	-	.050K	.010K
1/5/94	659	.050K	-	.050K	.010K
1/25/94	538	.050K	-	.050K	.010K
2/15/94	396	.050K	-	.050K	.010K
3/8/94	1,177	.050K	-	.050K	.010K
3/29/94	971	.050K	-	.050K	.010K
4/19/94	1,893	.050K	-	.050K	.010K
5/12/94	1,353	.050K	-	.050K	.010K
6/1/94	467	.050K	-	.050K	.010K
6/21/94	577	.050K	-	.050K	.010K

Note: K indicates off-scale low values.

Table A-2. Results for PEST1 Parameters, Hardin, Illinois River

Date	Q,cms	*Alachlor* µg/L	*Atrazine* µg/L	*Butylate* µg/L	*Captan* µg/L	*Chloropyrifos* µg/L	*Cyanazine* µg/L	*Diazinon* µg/L	*Fonofos* µg/L	*Malathion* µg/L	*Parathion* µg/L	*Metolachlor* µg/L
12/16/93	1,560	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
1/5/94	954	.020K	.050K	.050K	.050K	.050K	0.2	.050K	.050K	.050K	.050K	.10K
1/25/94	778	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	0.46
2/15/94	573	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
3/8/94	1,703	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
3/29/94	1,404	.020K	.050K	.050K	.050K	.050K	0.12	.050K	.050K	.050K	.050K	0.13
4/19/94	2,739	0.82	5.8	.050K	.050K	.050K	6.6	.050K	.050K	.050K	.050K	2.9
5/12/94	1,957	0.27	3.8	.050K	.050K	.050K	6.3	.050K	.050K	.050K	.050K	1.6
6/2/94	807	0.09	2.9	.050K	.050K	.050K	1.8	.050K	.050K	.050K	.050K	0.49
6/22/94	835	.020K	3.2	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K

Date	Q, cms	*Metribuzin* µg/L	*Phomte*	*Terbufos* µg/L	*Trifluralin* µg/L
12/16/94	1,560	.050K	-	.050K	.010K
1/5/94	954	.050K	-	.050K	.010K
1/25/94	778	.050K	-	.050K	.010K
2/15/94	573	.050K	-	.050K	.010K
3/8/94	1,703	.050K	-	.050K	.010K
3/29/94	1,404	.050K	-	.050K	.010K
4/19/94	2,739	.050K	-	.050K	.010K
5/12/94	1,957	.050K	-	.050K	.010K
6/2/94	807	.050K	-	.050K	.010K
6/22/94	835	.050K	-	.050K	.010K

Note: K indicates off-scale low values.

Table A-3. Results for PEST1 Parameters, Fulton, Mississippi River

Date	*Q, cms*	*Alachlor* *µg/L*	*Atrazine* *µg/L*	*Butylate* *µg/L*	*Captan* *µg/L*	*Chloropyrifos* *µg/L*	*Cyanazine* *µg/L*	*Diazinon* *µg/L*	*Fonofos* *µg/L*	*Malathion* *µg/L*	*Parathion* *µg/L*	*Metolachlor* *µg/L*
12/13/93	1,279	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
3/28/94	2,173	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
6/21/94	1,576	.020K	0.95	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K

Date	*Q, cms*	*Metribuzin* *µg/L*	*Phorate*	*Terbufos* *µg/L*	*Trifluralin* *µg/L*
12/13/93	1,279	.050K	-	.050K	.010K
3/28/94	2,173	.050K	-	.050K	.010K
6/21/94	1,576	.050K	-	.050K	.010K

Note: K indicates off-scale low values.

Table A-4. Results for PEST1 Parameters, Keokuk, Mississippi River

Date	Q.cms	Alachlor µg/L	Atrazine µg/L	Butylate µg/L	Captan µg/L	Chloropyrifos µg/L	Cyanazine µg/L	Diazinon µg/L	Fonofos µg/L	Malathion µg/L	Parathion µg/L	Metolachlor µg/L
12/14/93	1,757	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
1/4/94	1,344	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
1/24/94	1,274	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
2/14/94	1,225	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
3/7/94	3,792	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
3/28/94	3,000	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
4/18/94	2,553	0.06	.050K	.050K	.050K	.050K	0.11	.050K	.050K	.050K	.050K	.10K
5/11/94	4,387	.100K	0.93	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
6/1/94	1,973	.020K	0.36	.050K	.050K	.050K	0.17	.050K	.050K	.050K	.050K	.10K
6/21/94	1,842	.020K	2	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K

Date	Q, cms	Metribuzin µg/L	Phorate	Terbufos µg/L	Trifluralin µg/L
12/14/93	1,757	.050K	-	.050K	.010K
1/4/94	1,344	.050K	-	.050K	.010K
1/24/94	1,274	.050K	-	.050K	.010K
2/14/94	1,225	.050K	-	.050K	.010K
3/7/94	3,792	.050K	-	.050K	.010K
3/28/94	3,000	.050K	-	.050K	.010K
4/18/94	2,553	.050K	-	.050K	.010K
5/11/94	4,387	.050K	-	.050K	.010K
6/1/94	1,973	.050K	-	.050K	.010K
6/21/94	1,842	.050K	-	.050K	.010K

Note: K indicates off-scale low values.

Table A-5. Results for PEST1 Parameters, L & D 26, Mississippi River

Date	Q.cms	*Alachlor* *µg/L*	*Atrazine* *µg/L*	*Butylate* *µg/L*	*Captan* *µg/L*	*Chloropyrifos* *µg/L*	*Cyanazine* *µg/L*	*Diazinon* *µg/L*	*Fonofos* *µg/L*	*Malathion* *µg/L*	*Parathion* *µg/L*	*Metolachlor* *µg/L*
12/16/93	3,400e	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
1/6/94	2,324e	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
1/25/94	2,097e	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
2/15/94	1,400	0.14	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
3/8/94	5,299	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
3/29/94	3,826	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
4/19/94	5,724	0.24	1.5	.050K	.050K	.050K	1.9	.050K	.050K	.050K	.050K	0.75
5/12/94	6,461	0.12	0.42	.050K	.050K	.050K	1.8	.050K	.050K	.050K	.050K	0.39
6/2/94	2,763	.020K	0.82	.050K	.050K	.050K	0.62	.050K	.050K	.050K	.050K	0.2
6/22/94	2,834	.020K	2.4	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K

Date	Q, cms	*Metribuzin* *µg/L*	*Phorate*	*Terbufos* *µg/L*	*Trifluralin* *µg/L*
12/16/93	3,400e	.050K	-	.050K	.010K
1/6/94	2,324e	.050K	-	.050K	.010K
1/25/94	2,097e	.050K	-	.050K	.010K
2/15/94	1,400	.050K	-	.050K	.010K
3/8/94	5,299	.050K	-	.050K	.010K
3/29/94	3,826	.050K	-	.050K	.010K
4/19/94	5,724	.050K	-	.050K	.010K
5/12/94	6,461	.050K	-	.050K	.010K
6/2/94	2,763	.050K	-	.050K	.010K
6/22/94	2,834	.050K	-	.050K	.010K

Note: K indicates off-scale low values.

Table A-6. Results for PEST1 Parameters, Thebes, Mississippi River

		Alachlor	*Atrazine*	*Butylate*	*Captan*	*Chloropyrifos*	*Cyanazine*	*Diazinon*	*Fonofos*	*Malathion*	*Parathion*	*Metolachlor*
Date	*Q, cms*	*μg/L*	*μg/L*	*μg/L*	*μg/L*	*μg/L*	*μg/L*	*μg/L*	*μg/L*	*μg/L*	*μg/L*	*μg/L*
12/17/93	6,934	.020K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.050K	.10K
6/23/94	6,368	.020K	0.55	.050K	.050K	.050K	0.11	.050K	.050K	.050K	.050K	.10K

		Metribuzin		*Terbufos*	*Trifluralin*
Date	*Q. cms*	*μg/L*	*Phorate*	*μg/L*	*fjg/L*
12/17/93	6,934	.050K	-	.050K	.010K
6/23/94	6,368	.050K	-	.050K	.010K

Note: K indicates off-scale low values.

APPENDIX B

CORE2 Results

Table B-1. Results for CORE2 (PEST1) Parameters, Valley City, Illinois River

Date	*Q.cms*	*PCBs µg/L*	*Aldrin TOT µg/L*	*Dieldrin TOTµg/L*	*Tot. DDT µg/L*	*O,pDDE µg/L*	*p,p'DDT TOTµg/L*	*o,pDDD µg/L*	*p,p'DDD TOT µg/L*	*o,pDDT µg/L*	*p,p'DDT TOT µg/L*	*Chlordane µg/L*	*trans iso. WWS-µg/L*
12/15/93	1,109	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
1/5/94	659	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
1/25/94	538	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
2/15/94	396	.200K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
3/8/94	1,177	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
3/29/94	971	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
4/19/94	1,893	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
5/12/94	1,353	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/1/94	467	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/21/94	617	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K

Date	*Q, cms*	*Nonachlor cis iso µg/L*	*Nonachlor trans iso µg/L*	*Endrin µg/L*	*Meth Oxychlor µg/L*	*Hexachloro cyclo hexane µg/L*	*gamma BHC Lindane µg/L*	*Hexa chloro benzene µg/L*	*Penta chloro phenol µg/L*	*Chlordane cis isomer µg/L*
12/15/93	1,109	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
1/5/94	659	-	-	.010K	.050K	.010K	010K	.010K	.010K	.010K
1/25/94	538	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
2/15/94	396	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
3/8/94	1,177	-	-	.010K	.050K	.010K	.010K	.010K	.090	.010K
3/29/94	971	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
4/19/94	1,893	-	-	.010K	.050K	.010K	.010K	.010K	.020	.010K
5/12/94	1,353	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
6/1/94	467	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
6/21/94	617	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K

Note: K indicates off-scale low values.

Table B-2. Results for CORE2 (PEST1) Parameters, Hardin, Illinois River

Date	*Q.cms*	*PCBs µg/L*	*Aldrin TOT µg/L*	*Dieldrin TOT µg/L*	*Tot. DDT µg/L*	*O.pDDE µg/L*	*p.p'DDE TOT µg/L*	*o.pDDD µg/L*	*p.p'DDD TOT µg/L*	*o.pDDT µg/L*	*p.p'DDT TOT µg/L*	*Chlordane µg/L*	*trans iso. WWS-µg/L*
11/4/93	1,945	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
12/16/93	1,560.	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
1/5/94	954	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
1/25/94	778	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
2/15/94	573	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
3/8/94	1,703	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
3/29/94	1,404	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
4/19/94	2,739	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
5/12/94	1,957	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/2/94	807	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/22/94	835	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K

Date	*Q.cms*	*Nonachlor cis iso µg/L*	*Nonachlor trans iso µg/L*	*Endrin µg/L*	*Meth Oxychlor µg/L*	*Hexachloro cyclo hexane µg/L*	*gamma BHC Lindane µg/L*	*Hexa chloro benzene µg/L*	*Penta chloro phenol µg/L*	*Chlordane cis isomer µg/L*
11/4/93	1,945	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
12/16/93	1,560	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
1/5/94	954	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
1/25/94	778	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
2/15/94	573	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
3/8/94	1,703	-	-	.010K	.050K	.010K	.010K	.010K	.090	.010K
3/29/94	1,404	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
4/19/94	2,739	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
5/12/94	1,957	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
6/2/94	807	-	. -	.010K	.050K	.010K	.010K	.010K	.010K	.010K
6/22/94	835	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K

Note: K indicates off-scale low values.

Table B-3. Results for CORE2 (PEST1) Parameters, Fulton, Mississippi River

Date	*Q.cms*	*PCBs µg/L*	*Aldrin TOT µg/L*	*Dieldrin TOTµg/L*	*Tot. DDT µg/L*	*O.pDDE µg/L*	*p.p'DDT TOTµg/L*	*o,p µg/L*	*p.p'DDD TOTµg/L*	*o.pDDT µg/L*	*p.p'DDT TOT µg/L*	*Chlordcme µg/L*	*trxmsiso. WWS-µg/L*
12/13/93	1,279	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
3/28/94	2,173	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/21/94	1,576	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K

Date	*Q. cms*	*Nonachlor cis iso µg/L*	*Nonachlor trans iso µg/L*	*Endrin µg/L*	*Meth-Oxychlor µg/L*	*Hexachloro cyclo hexane µg/L*	*gamma BHC Lindane µg/L*	*Hexa chloro benzene µg/L*	*Penta chloro phenol µg/L*	*Chlordane cis isomer µg/L*
12/13/93	1,279	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
3/28/94	2,173	-	-	.010K	.050K	.010K	.010K	.010K	.020	.010K
6/21/94	1,576	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K

Note: K indicates off-scale low values.

Table B-4. Results for CORE2 (PEST1) Parameters, Keokuk, Mississippi River

Date	*Q.cms*	*PCBs µg/L*	*Aldrin TOTµg/L*	*Dieldrin TOT µg/L*	*Tot. DDT µg/L*	*O, p DDE µg/L*	*p.p'DDT TOT µg/L*	*o.pDDD µg/L*	*p.p'DDD TOT µg/L*	*o.pDDT µg/L*	*p.p'DDT TOT µg/L*	*Chlordane µg/L*	*trans iso. WWS-µg/L*
12/14/93	1,757	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
1/4/94	1,344	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
1/24/94	1,274	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
2/14/94	1,225	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
3/7/94	3,792	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
3/28/94	3,000	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
4/18/94	2,553	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
5/11/94	4,387	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/1/94	1,973	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/21/94	1,842	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K

Date	*Q, cms*	*Nonachlor cis iso µg/L*	*Nonachlor trans iso µg/L*	*Endrin µg/L*	*Meth-Oxychlor µg/L*	*Hexachloro cyclo hexane µg/L*	*gamma BHC Lindane µg/L*	*Hexa chloro benzene µg/L*	*Penta chloro phenol µg/L*	*Chlordane cis isomer µg/L*
12/14/93	1,757	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
1/4/94	1,344	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
1/24/94	1,274	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
2/14/94	1,225	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
3/7/94	3,792	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
3/28/94	3,000	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
4/18/94	2,553	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
5/11/94	4,387	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
6/1/94	1,973	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
6/21/94	1,842	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K

Note: K indicates off-scale low values.

Table B-5. Results for CORE2 (PEST1) Parameters, L & D 26, Mississippi River

Date	*Q.cms*	*PCBs µg/L*	*Aldrin TOT µg/L*	*Dieldrin TOT µg/L*	*Tot. DDT µg/L*	*O.pDDE µg/L*	*p.p'DDT TOT µg/L*	*o.pDDD µg/L*	*p.p'DDD TOT µg/L*	*o.pDDT µg/L*	*p.p'DDT TOT µg/L*	*Chlordane µg/L*	*trans iso. WWS-µg/L*
12/16/93	1,560	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
1/6/94	954	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
1/25/94	778	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
2/15/94	573	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
3/8/94	1,703	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
3/29/94	1,404	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
4/19/94	2,739	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
5/12/94	1,957	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/2/94	807	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/22/94	835	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K

Date	*Q.cms*	*Nonachlor cis iso WWS-µg/L*	*Nonachlor trans iso WWS-µg/L*	*Endrin TOT µg/L*	*Meth-Oxychlor µg/L*	*Hexachloro cyclo hexane TOT µg/L*	*gamma BHC Lindane TOT µg/L*	*Hexa chloro benzene TOT µg/L*	*Penta chloro phenol TOT µg/L*	*Chlordane cis isomer WWS-µg/L*
12/16/93	1,560	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
1/6/94	954	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
1/25/94	778	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
2/15/94	573	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
3/8/94	1,703	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
3/29/94	1,404	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
4/19/94	2,739	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
5/12/94	1,957	-	-	.010K	.050K	..010K	.010K	.010K	.010K	.010K
6/2/94	807	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K
6/22/94	835	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K

Note: K indicates off-scale low values.

Table B-6. Results for CORE2 (PEST1) Parameters, Thebes, Mississippi River

Date	*Q.cms*	*PCBs fjg/L*	*Aldrin TOT µg/L*	*Dieldrin TOT µg/L*	*Tot. DDT µg/L*	*O.pDDE µg/L*	*p.p'DDT TOT µg/L*	*o.pDDD µg/L*	*p.p'DDD TOT µg/L*	*o.pDDT µg/L*	*p.p'DDT TOT µg/L*	*Chlordane µg/L*	*trans iso. WWS-µg/L*
12/17/94	6,934	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K
6/23/94	6,368	.100K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.010K	.020K	.010K

Date	*Q,cms*	*Nonachlor cis iso µg/L*	*Nonachlor trans iso µg/L*	*Endrin µg/L*	*Meth-Oxychlor µg/L*	*Hexachloro cyclo hexane µg/L*	*gamma BHC Lindane µg/L*	*Hexa chloro benzene µg/L*	*Penta chloro phenol µg/L*	*Chlordane cis isomer µg/L*
12/17/94	6,934	-	-	.010K	.050K	.010K	.010K	.010K	.070	.010K
6/23/94	6,368	-	-	.010K	.050K	.010K	.010K	.010K	.010K	.010K

Note: K indicates off-scale low values.

APPENDIX C

Data Plots for Selected CORE4 Parameters

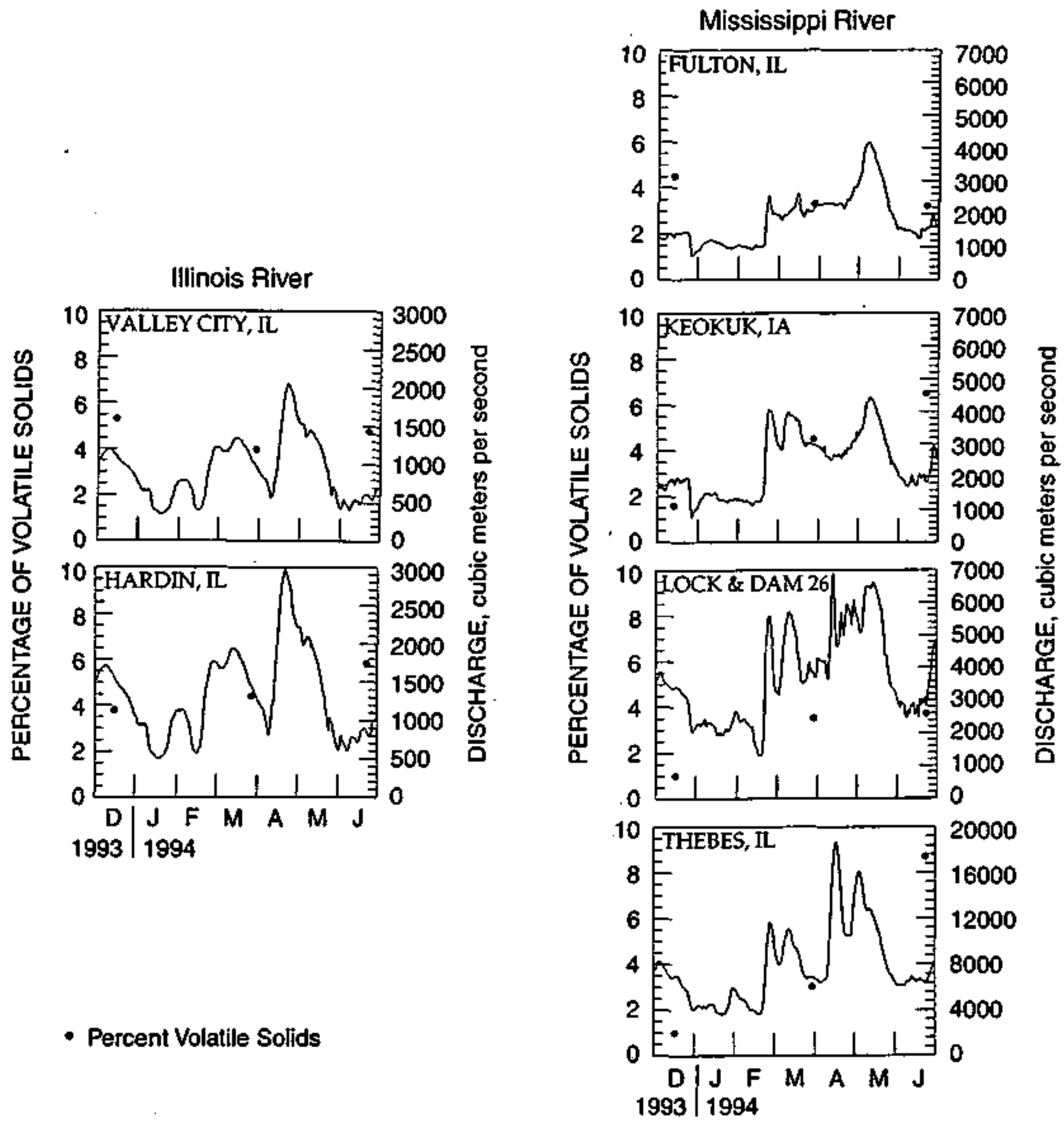

Figure C-l. Percentage of Volatile Solids at each Sampling Station during the Study Period

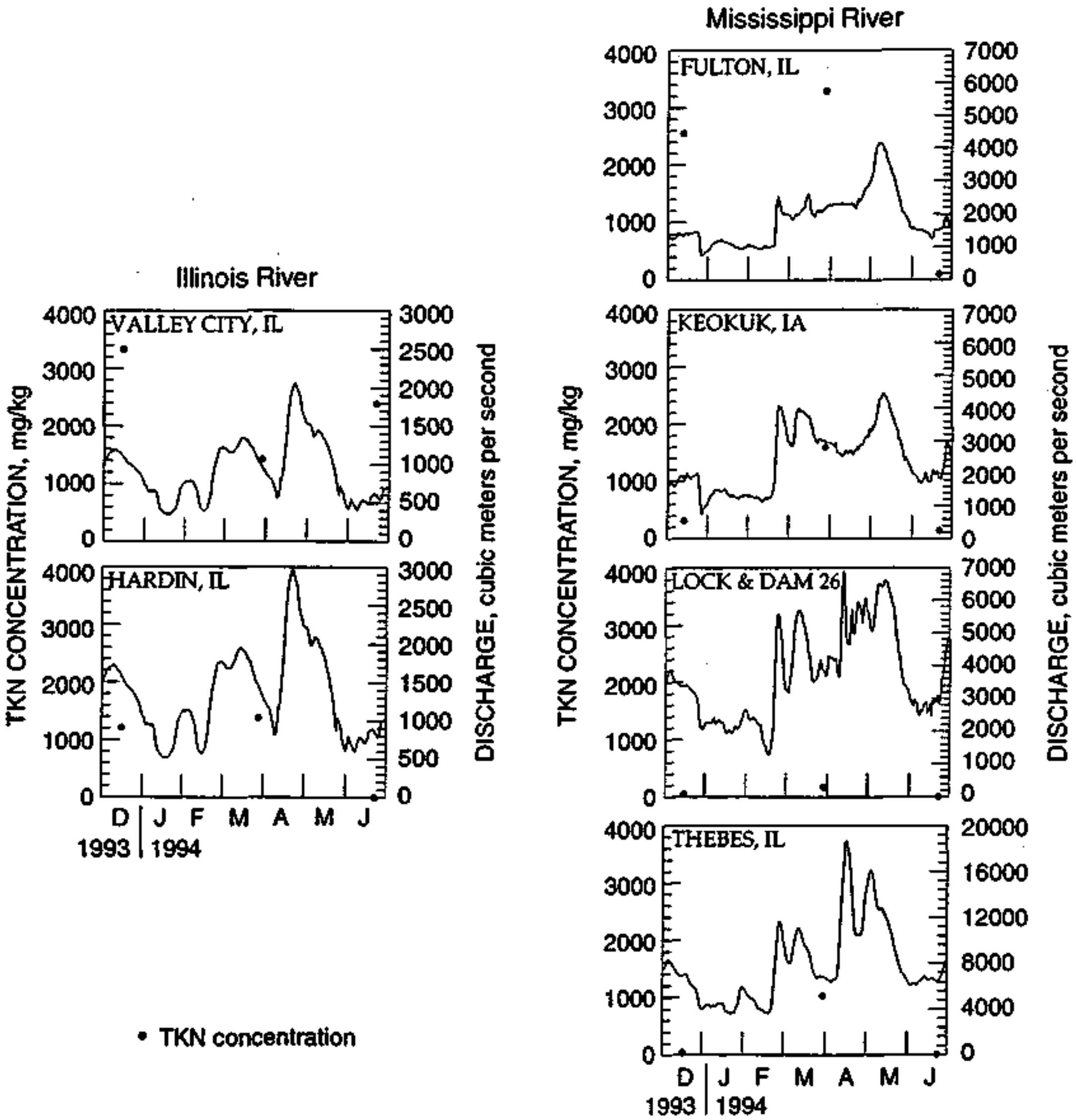

Figure C-2. TKN Concentrations at each Sampling Station during the Study Period

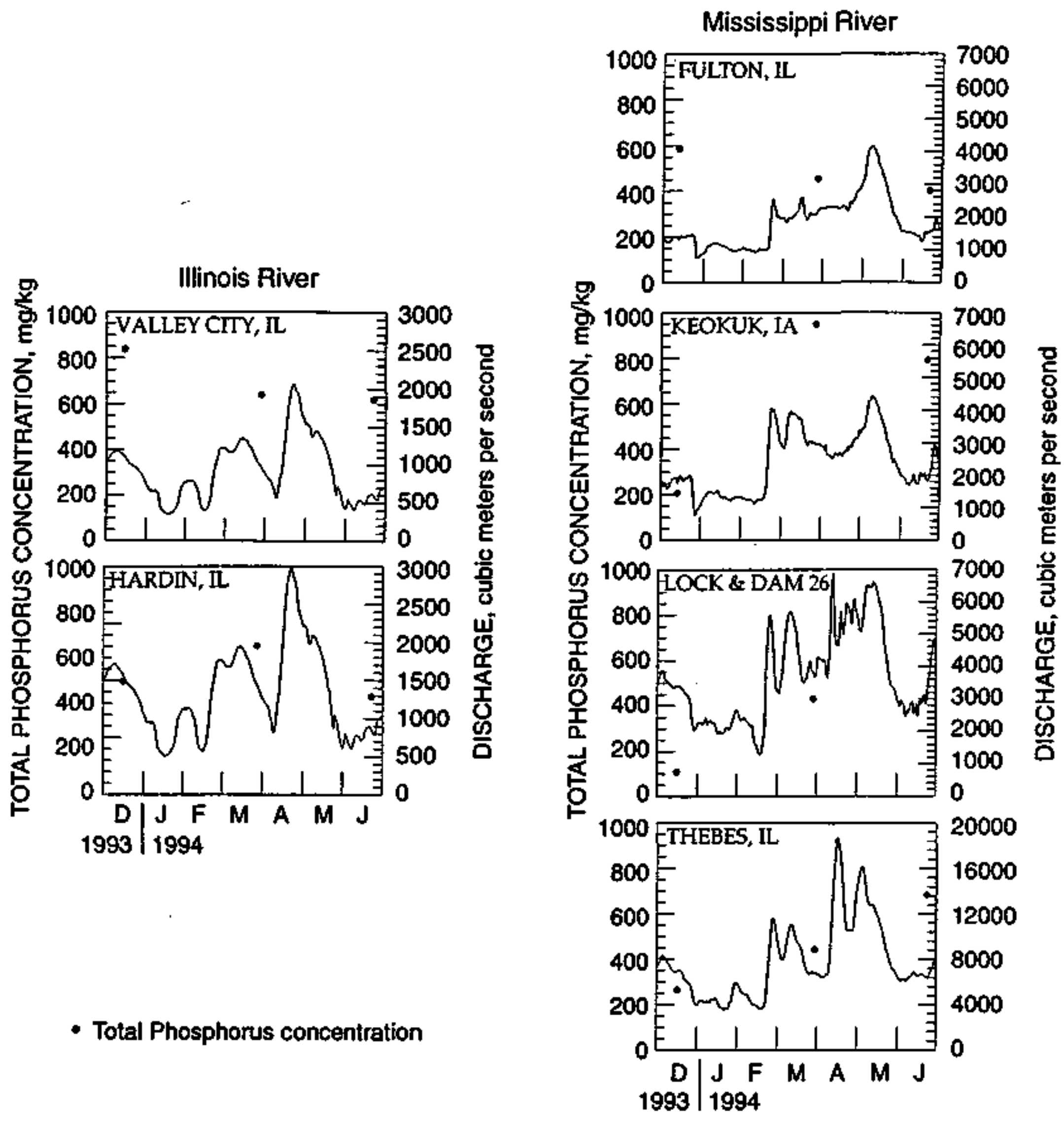

Figure C-3. Total Phosphorus Concentrations at each Sampling Station during the Study Period

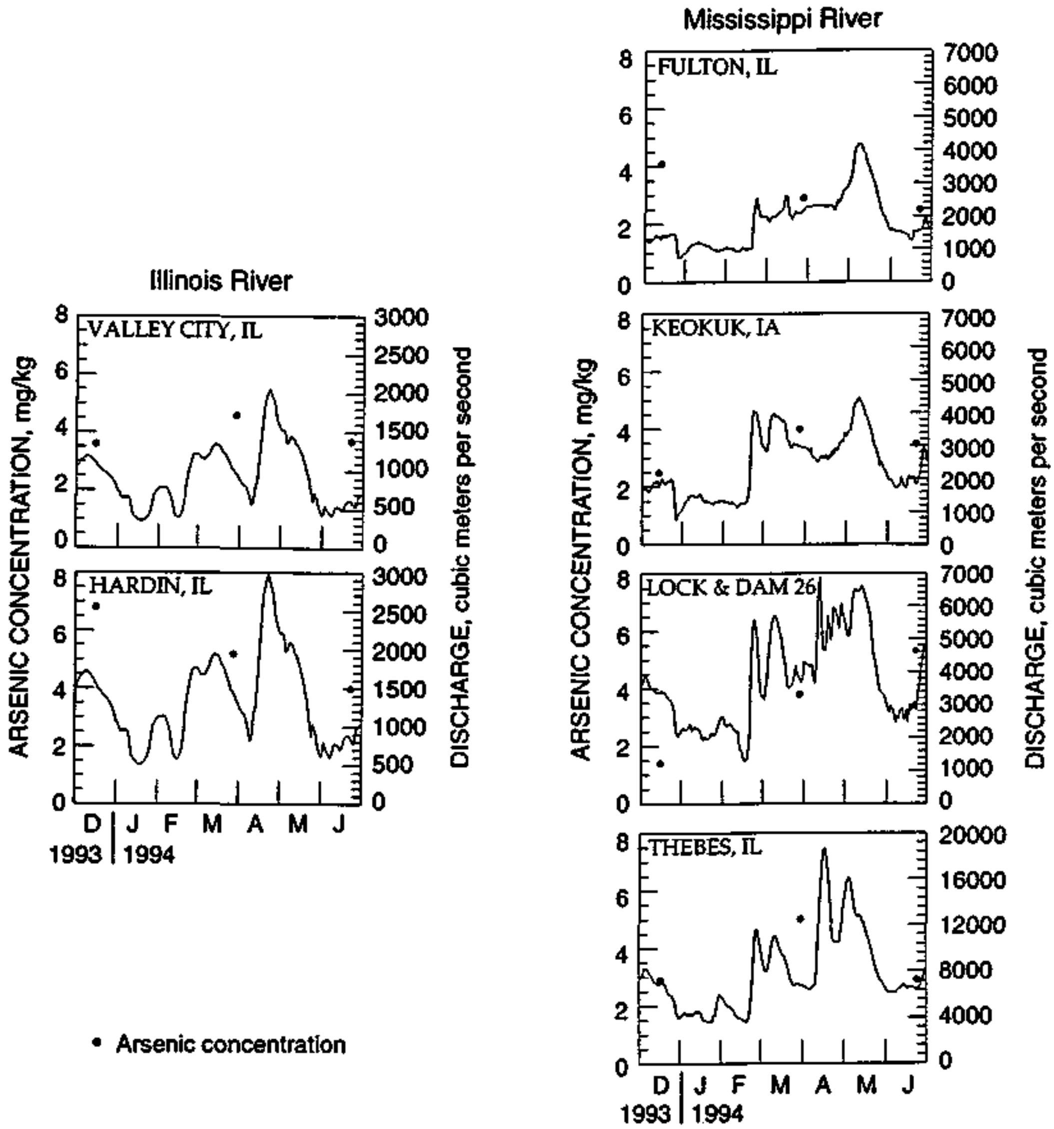

Figure C-4. Arsenic Concentrations at each Sampling Station during the Study Period

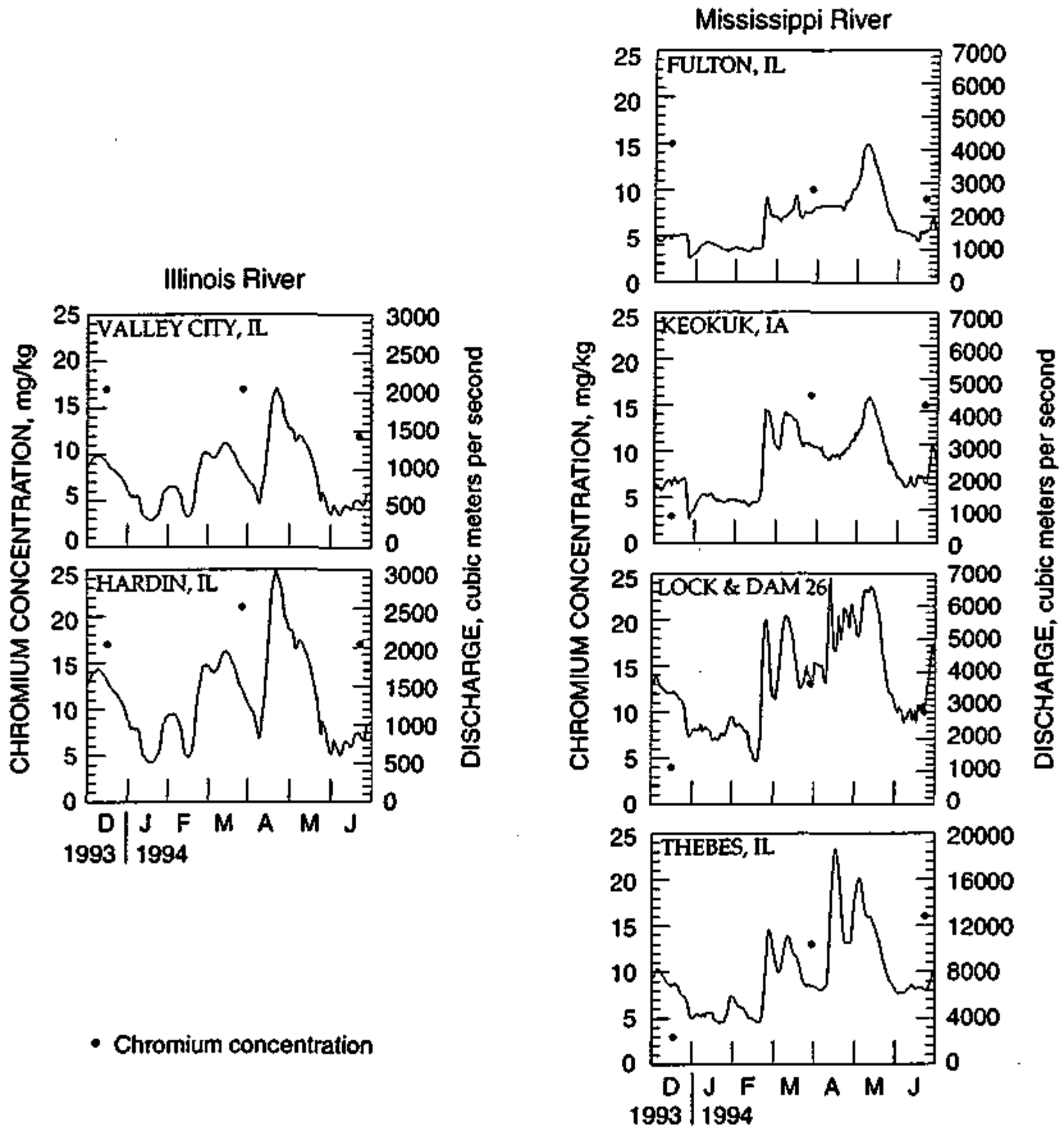

Figure C-5. Chromium Concentrations at each Sampling Station during the Study Period

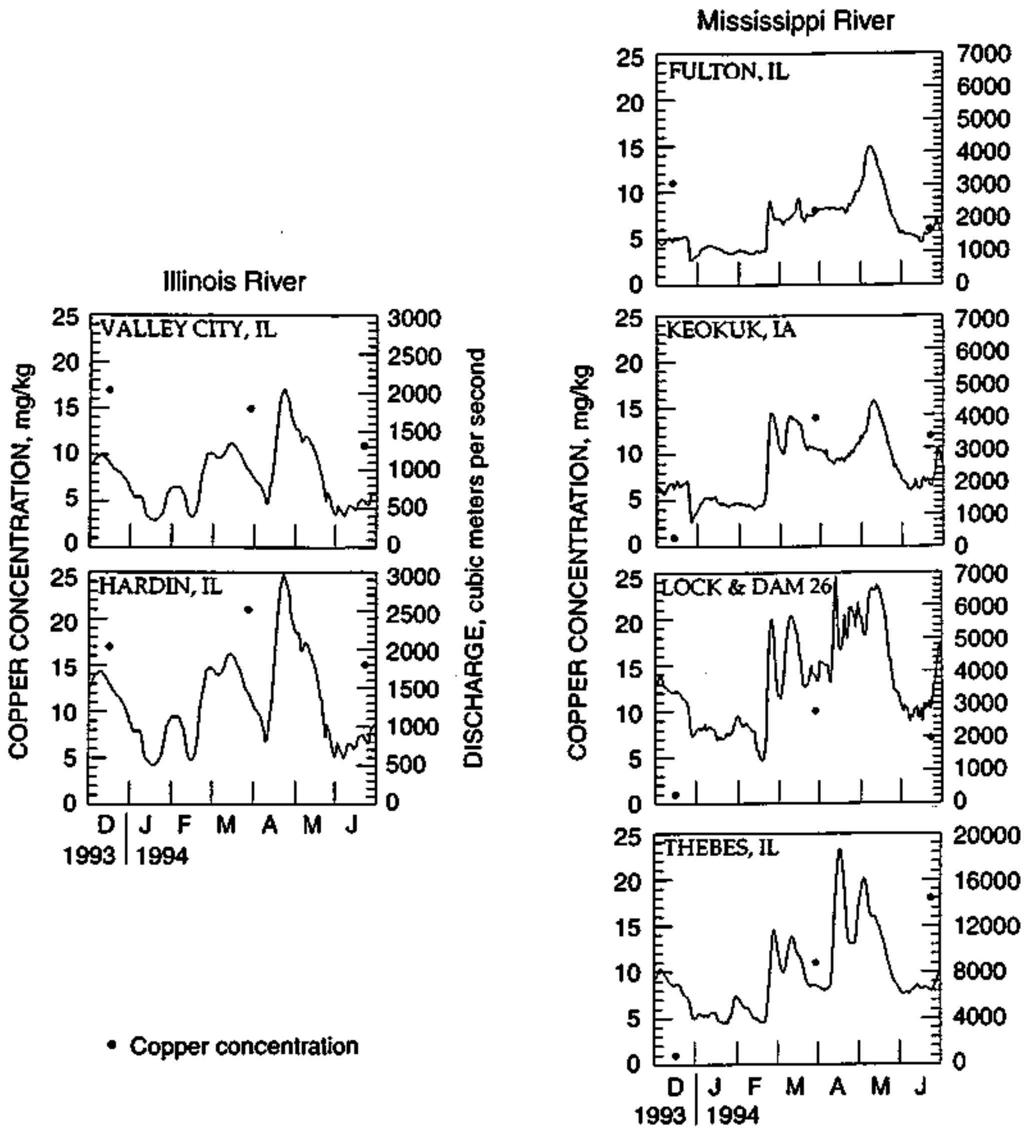

Figure C-6. Copper Concentrations at each Sampling Station during the Study Period

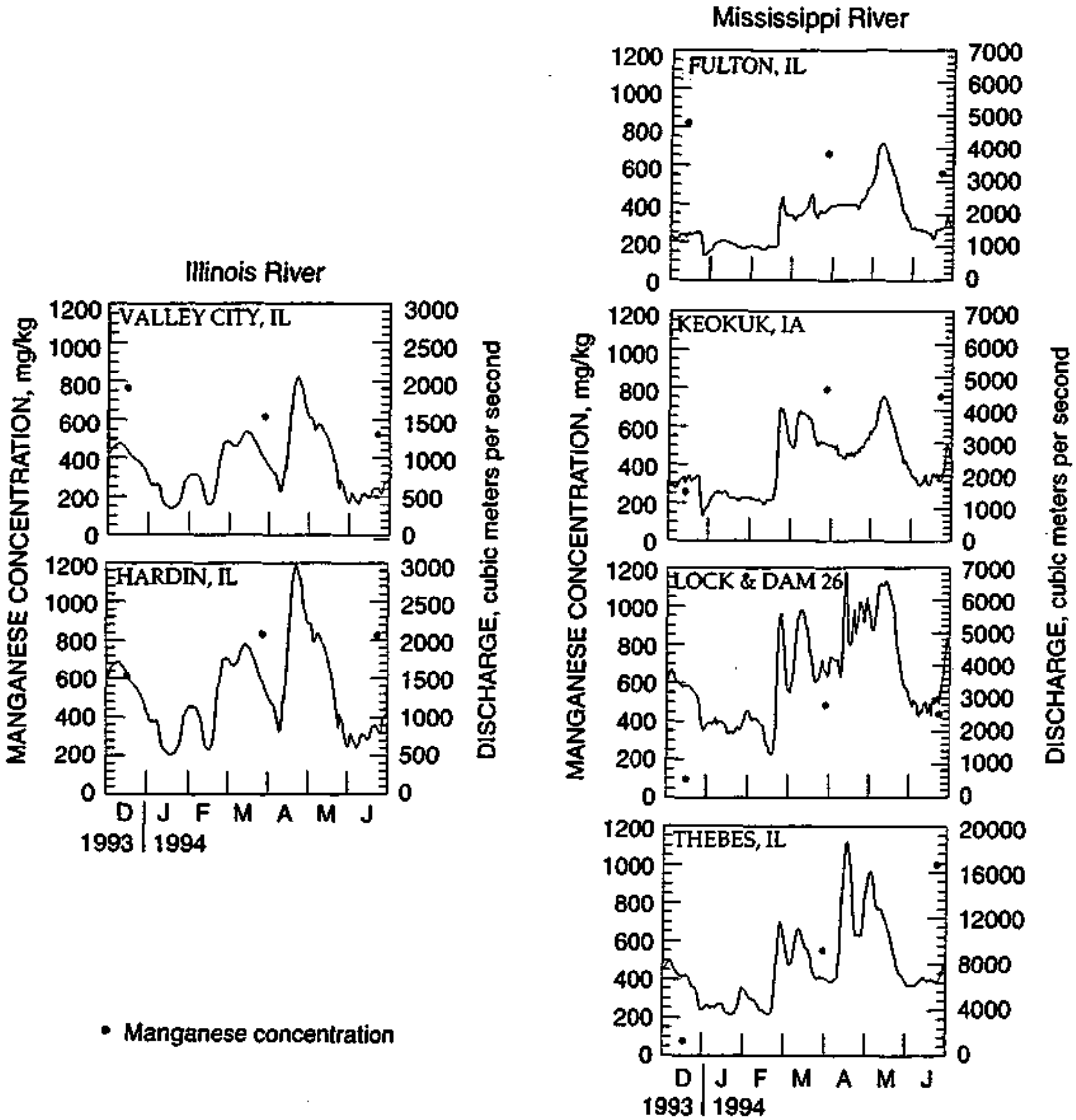

Figure C-7. Manganese Concentrations at each Sampling Station during the Study Period

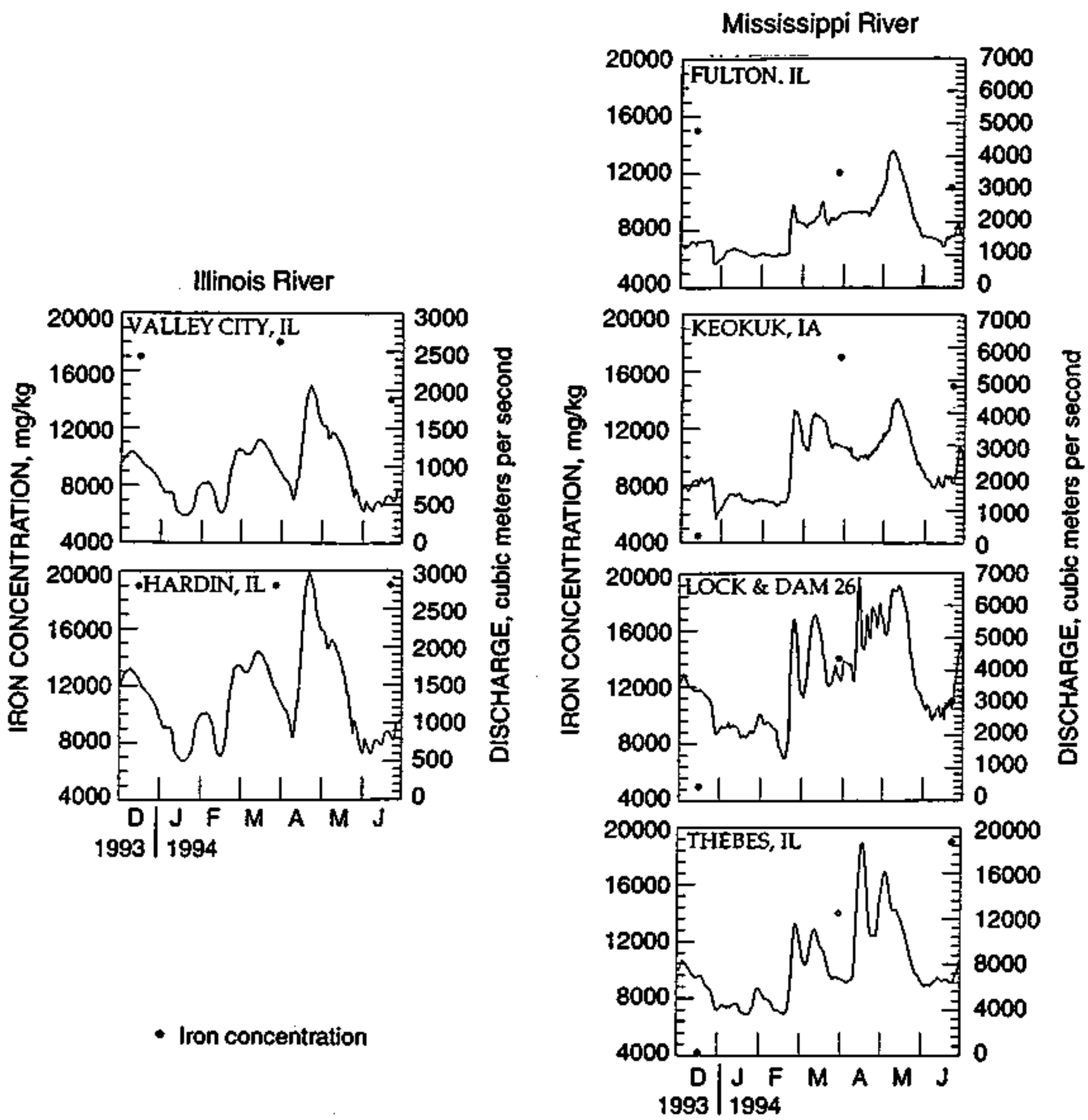

Figure C-8. Iron Concentrations at each Sampling Station during the Study Period

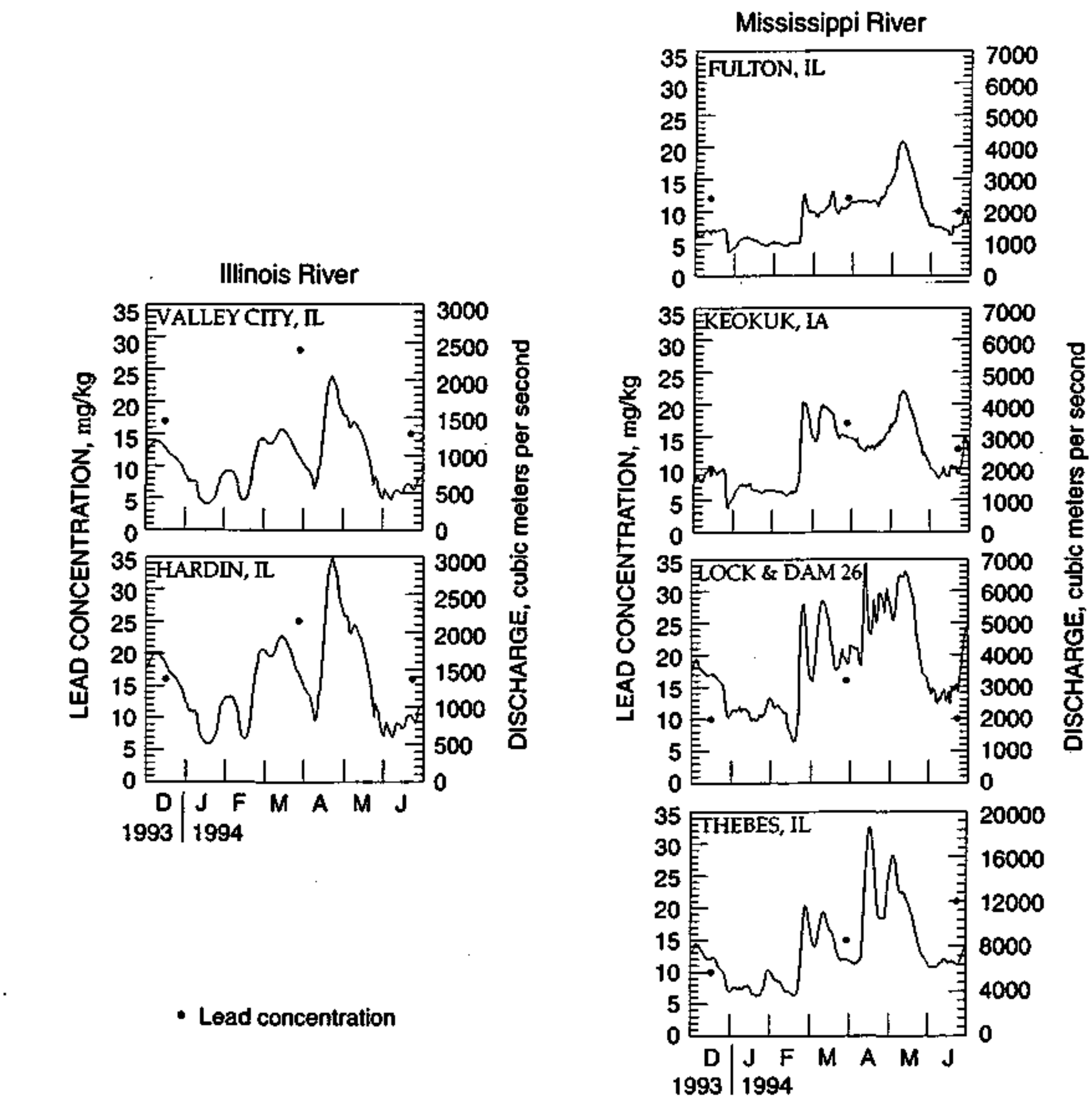

Figure C-9. Lead Concentrations at each Sampling Station during the Study Period

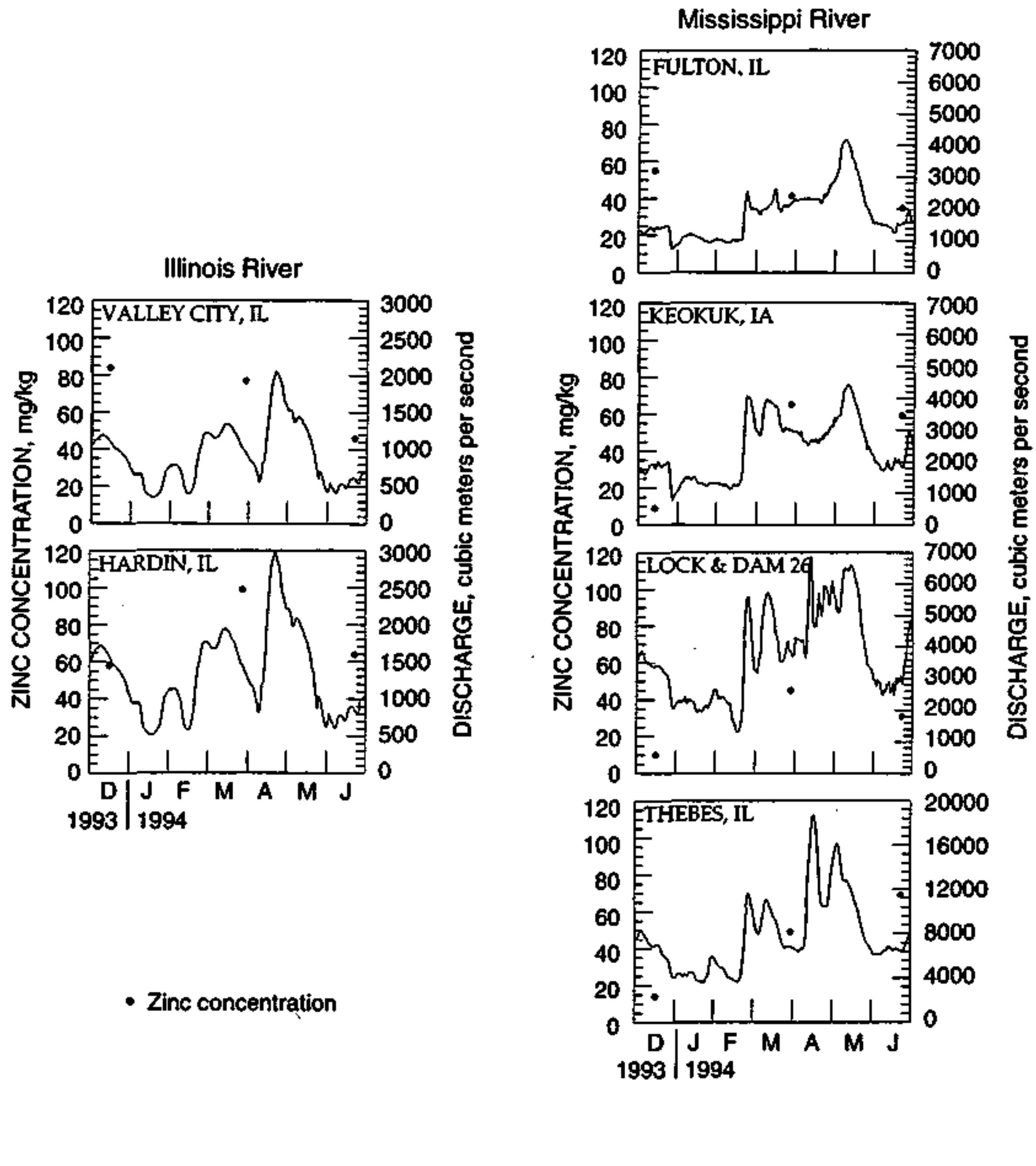

Figure C-10. Zinc Concentrations at each Sampling Station during the Study Period

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